National Law Enforcement and Corrections Technology Center

Understanding Wireless Communications in Public Safety

A Guidebook to Technology, Issues, Planning, and Management

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The National Law Enforcement and Corrections Technology Center–Rocky Mountain

The National Law Enforcement and Corrections Technology Center (NLECTC) system was created in 1994 as a component of the National Institute of Justice's (NIJ's) Office of Science and Technology. NLECTC's goal, like that of NIJ, is to offer support, research findings, and technological expertise to help State and local public safety personnel do their jobs safely and efficiently.

NIJ's NLECTC system consists of facilities located across the country that are colocated with an organization or agency that specializes in one or more specific areas of research and development. Although each of the NLECTC facilities has a different technology focus, they work together to form a seamless web of support, technology development, and information to help the public safety community.

Located at the University of Denver, NLECTC–Rocky Mountain focuses on communications interoperability and the difficulties that often occur when different agencies and jurisdictions try to communicate with one another. This facility works with public safety agencies, private industry, and national organizations to implement projects that will identify and field test new technologies to help solve the problems of interoperability. NLECTC–Rocky Mountain also houses the newly created Crime Mapping Technology Center, the training and practical application arm of NIJ's Crime Mapping Research Center. The Rocky Mountain facility also conducts research into ballistics and weapons technology, as well as information systems.

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INTRODUCTION

The National Law Enforcement and Corrections Technology Center (NLECTC) system was conceived with the idea of helping public safety personnel understand and use new technology. In keeping with that goal, NLECTC–Rocky Mountain developed this guidebook to help unravel the confusing issues, terms, and options surrounding wireless communications, particularly as it involves commercially available communications services.

The target audience consists of those middle and upper managers who are responsible for funding and/or managing communications at their agencies, but who have little or no technical background in wireless technology.

This guidebook is divided into four parts:

Part 1. Planning and Managing a Communications Project: Discusses the overall scope of a project, including planning, funding, procurement, and management.

Part 2. Wireless Communications Technology: Discusses voice versus data, characteristics of radio systems (including terminology), and current types of public safety radio systems.

Part 3. Wireless Communications Issues: Discusses Federal Communications Commission (FCC) licensing, rules, regulations, and related issues; radio frequency radiation exposure; and the Federal Bureau of Investigation's (FBI's) National Crime Information Center (NCIC) 2000 project.

Part 4. Wireless Communications Options: Discusses voice system options, data system options, and the latest developments in communications technology.

Each section can be read separately from and independently of the others. If all you want to know is what your options are, go directly to part 4. However, if you are not familiar with how the various wireless options work and the terms used, you may first want to read part 2.

No one book can possibly cover everything you might ever need to know if you are planning a communications project. However, the authors will at least try to highlight the main issues and explain the terminology so that you can be an informed consumer. In addition, the authors have tried to point you toward other resources that will provide more detail about areas you want to understand better.

At various places in the document, you will find highlighted information and/or suggestions to make things go a little quicker or easier for you. Those tips are placed in boxes like the one to the right.

> ☞ Try this...
>
> Identify wireless carriers in your area at CTIA's Web site:
>
> http:/www.wow-com.com

At the end of the document is a glossary of common wireless terms, as well as a list of the acronyms you may run into. (Note: The number of terms and acronyms used in this industry is *huge*. For the sake of brevity, only the most common are included.)

If, after you have read this guidebook, you still have questions or need help, contact NLECTC–Rocky Mountain by phone at 800–416–8086 or 303–871–2522 in the Denver area or via the Internet at nlectc@du.edu.

PART 1

PLANNING AND MANAGING A COMMUNICATIONS PROJECT

Part 1 gives an overview of the steps involved in a communications project. Chapter 1 discusses the steps needed to be successful. Chapter 2 covers the planning process. Chapter 3 identifies various potential sources of funding for projects of this type. Chapter 4 goes through the procurement process itself, with details for those who have never been involved in a large-scale competitive procurement.

For those who have managed projects before, who already have identified funding, or who are familiar with purchasing requirements, you may want to skip part 1 and go directly to part 2.

Chapter 1

What It Takes to Succeed

Successful projects are usually the result of careful planning. Planning helps to create a disciplined, businesslike approach to the project and fosters communication among groups, often resulting in partnerships.

A Plan

The first step in planning is to gather information about agency needs, available assets and resources, existing communications infrastructure, end-user requirements, and other related issues.

A plan is important because it defines the project's goals, describes the specific problems or needs that are being addressed, lists any potential partners and their roles, identifies staffing requirements, outlines a marketing strategy, proposes a detailed budget and time line, and includes an operational plan that addresses how the project will be funded now and into the future.

A good plan should list all tasks, including flowcharts, schedules, and task budgets. A number of software programs, particularly project management software tools, are available that help make creating and maintaining these much easier.

Time, Money, and Resources

No project can succeed without adequate amounts of time, money, and other resources. Thus, to be successful, time must be allocated to:

- ➡ Identify, recruit, and assign or hire necessary staff.
- ➡ Identify potential project partners and create formal relationships.
- ➡ Identify potential sources of funding and apply for funds.
- ➡ Identify and procure appropriate communications technologies.
- ➡ Implement the project.

The following sections in part 1 will discuss the issues of time, money, and resources in more detail.

Getting Started

Before going forward on a communications project, you will need to answer a number of questions. While collecting the information may seem tedious, you will be well rewarded down the line when you find that you are asked to provide this same information to potential funding sources, management, and others.

What Do You Have Now?

One of the first things you need to identify are your existing business functions. In other words, answer the questions:

➡ What do we do?
➡ How do we do it?
➡ What are our core functions?
➡ How does or will technology support those functions?

Plus, you should try to identify the benefits of such a project, both the tangible, measurable benefits (decreased maintenance costs, improved coverage, etc.) and the intangible benefits (improved morale, better customer service, etc.).

In addition, you should make an inventory of all of your existing communications hardware and software and frequency licenses. The inventory should include as many of the following as possible:

➡ Quantity.

➡ Manufacturer, make, model (or version number of software).

➡ Year of installation/purchase.

➡ Year last upgraded.

➡ Frequency of use.

➡ Purpose (what it is used for).

➡ Location.

➡ Owner (for example, radio towers may be leased rather than owned by the agency, but should still be included in the inventory).

➡ User (the type of agency and/or personnel, not necessarily the specific individual).

- ➡ Original cost.
- ➡ Estimated remaining useful life (in years).

In addition, you should identify the human resources that are potentially available to work on the project, including their skills and current assignment.

What Do You Need?

Identifying what you need is not simply making a list of equipment. You should start at a much higher level and try to determine the kinds of functions/tasks you want to be able to perform. Are you wanting to add new capabilities to your existing system? What are they? Who will use them, and how often? Will the existing system support those new capabilities?

For example, if you want to be able to put mobile data computers into your vehicles, you will need to ask yourself a series of questions, such as What will the computers be used for? Will they need to communicate with computers in other locations? What locations? What kind of data will be passed over the radio system (dispatch messages, wants and warrants, field reports, a combination)? How much data? How much growth do you expect over the next 5 to 10 years? What kind of software applications will need interfaces (computer-aided dispatch, records management systems, automatic vehicle location system, geographical information system, etc.)?

Knowing what you hope to accomplish in the long term will also help you identify the solution that will best fit your needs. Use documents such as your agency's strategic plan (perhaps you call it a 5-year plan or some other similar name) to help determine your needs. For example, if your agency is planning to consolidate with another nearby agency within the next 5 years, your communications needs may be dramatically different from those required for just your agency alone. In addition, review the strategic plan(s) for the government entity you are part of (city, county, State) to see if its plans might provide you with some assistance. Review the plans of other government entities that have wireless communications needs (information systems, telecommunications, and various utility departments are often good sources of information).

Review your inventory to see how much, if any, of your existing equipment should be retained. What equipment will need to be replaced because it is obsolete or too expensive to maintain?

What Are Your Options?

Now that you know what you have and what you need (at a functional level), you are ready to start reviewing your options. Essentially you will be faced with two options: purchasing a dedicated system or contracting with a commercial service provider.

In certain rural areas of the United States with small populations, there may not be any commercial service providers. In that case, the only option will be purchasing a dedicated system. Chapter 3 discusses different funding sources, as well as partnering with other agencies as a means to obtain more "bang for the buck."

If you are in an area of the country that has access to commercial services, you will have to research the available services providers for cost, coverage, services, level of support, etc., to determine how well their services meet your needs (see part 4 for a complete discussion of your options).

How Much Will It Cost?

Cost is one of the most difficult items to accurately predict because certain critical items are often left out. The purchase price of the equipment or service alone is not sufficient to understand how much a system will cost you over a 10-year period (the average lifespan of a communications system). You need to look at the full life cycle cost of the system, including such things as maintenance, personnel, and license costs.

In addition to identifying the costs, you should also try to identify any cost savings that will result from implementing your project. What will you not have to pay for anymore once your project is installed? The cost savings will help offset the costs, thus reducing your overall life cycle cost.

Table 1-1 below compares a hypothetical agency's costs to operate a purchased, dedicated, mobile data system with its costs to operate a commercially provided system. (Note: These numbers should not be interpreted as examples of what actual costs would be to operate your system. Every agency is different, and vendor prices for equipment and services vary widely.)

Table 1-1. Ten-Year Life Cycle Costs—Mobile Data System

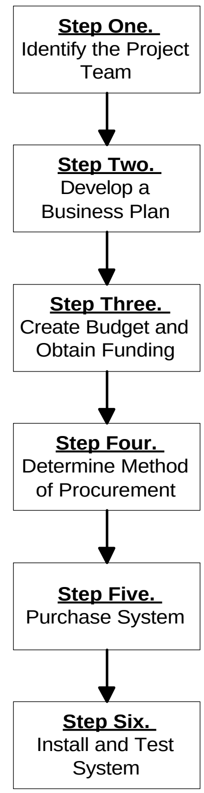
Agency Costs	**Purchase**	**Service Agreement**
Infrastructure Cost	$500,000	$0
Mobile equipment (25 cars @ $5,000 each)	$125,000	$125,000
Mobile software (25 cars @ $800 each)	$20,000	$20,000
Airtime (25 cars @ $50/month/car)	$0	$150,000
Infrastructure maintenance (approximately 10% of purchase price/year)	$500,000	$0
TOTAL	$1,145,000	$295,000

Most commercial vendors or service providers will be happy to provide you with budgetary information to help you plan your project. The information you gathered in your inventory and during your needs analysis should be provided to them to allow them to estimate their costs as accurately as possible.

How Do You Implement the Project?

The overall steps needed to implement a project like this are identified in figure 1-1. Each is important. Additional details regarding planning of the project (part of steps one and two), obtaining of funds (step three), and the procurement process (steps four through six) are given in subsequent chapters.

Figure 1-1. Project Steps



Getting Help

At this point you may be starting to feel a little overwhelmed with the size and complexity of the project you have taken on. Don't. Many agencies, both large and small, have successfully undertaken radio projects over the years. However, if you still feel that this task is beyond your ability to handle or will take more time than you can reasonably provide, you can get help from a number of sources (also see resources in appendix D).

Other Agencies

Other agencies near you have done this before. If you do not know who to call, contact your local Association of Public-Safety Communications Officials (APCO) chapter and ask them for a list of agencies that have recently completed a project similar to yours. Ask them for help. They are usually glad to send you copies of requests for proposals (RFPs), contracts, coverage requirements, system test plans, or any other type of sample documentation you may need. They may even be willing to sit down and discuss how they managed their project and make suggestions for yours.

Remember that, like you, they also have a full-time job working for their own agency. They won't be able to do the project for you. But, if you need is a sounding board for ideas, most people are happy to do what they can.

Consultants

If you decide that you need more dedicated and expert help than can be obtained from your neighbor agencies, you may want to consider hiring a consultant. A consultant can perform a number of the project tasks for you, from conducting the inventory and needs analysis to developing budgetary cost estimates to creating an RFP to assisting you with the project management. You determine the level and extent of services you wish to purchase.

Many consultants will perform your work as a fixed-price contract, provided you can clearly identify the scope of work you wish them to perform. Otherwise, you can hire a consultant on a time and materials basis. In the latter case, your risk is higher, since you may not have any cap on the amount of money spent or any guarantee that your project will be finished when you run out of money to pay the consultant. The authors recommend, whenever possible, that you create a clear scope of work and have the consultant give you a firm quote. Have proposers provide you with unit costs (hourly rate) for additional work and set “not to exceed” limits.

Depending on your agency’s purchasing rules, you may need to create an RFP for consulting services. If you do, follow the same general steps that are outlined in chapter 4 for competitive procurements.

Again, your nearby agencies are a great source of information about consultants. They can tell you who they have used and tell you whether they were satisfied with the consulting firm’s services. Make sure that when you are evaluating potential consultants they have completed similar projects.

Vendors

One of the most useful sources of information are the vendors of the products you are considering. Many have created libraries of articles (often called “white papers”) written by industry experts, which explain the advantages and disadvantages of the various technologies. Most want to help educate you because they know that the better informed you are, the better buying decision you will make. Just remember that they are trying to sell you their product, so accept their information, but do the product comparisons yourself.

Chapter 2

Planning the Project

Realistic Schedule

One of the first things you need to develop when planning your project is an implementation schedule. The schedule should identify all major tasks and milestones and should allow enough time for the project to be developed, funded, and implemented. If you are applying for a grant, you may also need to add a period after implementation to comply with the grant's evaluation requirements.

A clear time line, identifying all of the milestones you expect to reach during the various phases of the project's implementation, is essential. Not only will it help all of your team to understand what has to be done and when, it will help reviewers get a much better perspective on what you are proposing.

Project Team(s)

Some projects are large enough that two project teams are needed and formed: a project *steering committee* and a project *implementation team.*

The *steering committee* is usually more involved with high-level planning and policy decisions, without getting actively involved in the details of the project. The steering committee often is composed of high-level representatives of the user agencies and/or departments, such as city/county managers, sheriffs, police and fire chiefs, finance directors, and sometimes elected officials. The purpose of the steering committee is to ensure support for the project at the highest levels of the organization. You need political, financial, and administrative support for your project to become a reality. Without that support, your project may never even get started, regardless of the need.

The other project team (or the only one in those cases where two teams are not needed or perhaps not possible) is the *implementation team*. The implementation team is the keystone upon which your project's success depends. This team must have the ability to effectively deal with both the technical complexity of a communications project and the organizational challenges associated with managing the project.

Project Manager

Like any other team, the person selected to lead the implementation group is critical. The key abilities needed in the project manager are organizational skills and people skills. Knowledge of the technical aspects of the project is helpful, but not critical. The project manager ensures that the team works smoothly together, makes sure that all tasks are completed on time and correctly, and solves the various problems that arise during the project. Pick someone who knows how to get things done.

Regardless of the skill of the project manager, that person will not be effective if he or she is not given the following:

Responsibility. The project manager must know that the ultimate success of the project is dependent on him or her and also that he or she will be held accountable for the project's success or failure.

Authority. No manager can succeed if given the responsibility but not the authority to make sure the necessary project tasks are carried out. The project manager must be empowered by the steering committee or other executive sponsor of the project to get and use whatever resources are needed to make the project a success.

Time. One of the most frequent causes for the delay or failure of a large project is not giving the project manager the time needed to do the job. Expecting to take someone who is currently doing one full-time job and assigning the project management tasks to him or her as well is just poor management. Estimate the time needed to effectively manage the project and then adjust the project manager's workload accordingly. Be sure to include time for unseen delays and for fine-tuning once the project is operational.

Management support. If a project manager's manager does not support the project, it is unlikely that the project manager will be successful. Make sure that the person selected has the backing of his or her management team.

Physical resources. It may seem obvious, but an adequate space within which to work is an absolute necessity. The project manager will spend hours on the telephone, in meetings, and reviewing detailed technical documents. Adequate space, privacy, and quiet are mandatory. Administrative support for tasks such as copying, filing, typing, and scheduling make the project manager more productive.

Other Team Members

Implementation team members should be selected to provide the project with the best chance for success. Each member should bring a unique perspective to the group. One could be technical. Others might be financial (including finance, budget, and purchasing) and legal. Still more might represent different aspects of the user community. (And don't forget to include your vendor on your team, once a vendor has been selected. Including the vendor on your team will minimize the chance of any last minute, unhappy surprises.)

Whatever their qualifications, team members should be willing to take on the assignment of certain tasks from the implementation schedule and have the time to accomplish those tasks. Like the project manager, team members must be willing to embrace the responsibility of performing their assignments and be allowed the time by the employing organizations to do those assignments well.

Budget

For funding administrators to evaluate your request for funds, you must be able to explain your budget in detail, particularly if you are applying for Federal funds. The budget must be reasonable for the tasks and equipment proposed, and the relationship of the budget to the project plan must be clearly identified and communicated.

Budgets should include all costs associated with the project. This could include costs for personnel, fringe benefits, computer hardware and software, other end-user equipment, telecommunications services and related equipment, furniture and space, supplies, and maintenance. If a new facility is needed to house personnel and/or equipment, construction costs may also be included.

If you are applying for a State or Federal grant, make sure you obtain a copy of the grant application guidelines (see resources in appendix D). Most grants require detailed budget information and mandate that it follow a specific format. Failure to follow the rules often results in immediate disqualification of the grant application.

Chapter 3

Obtaining Funds

For many agencies, obtaining funds is the most difficult part of a communications project. Projects like this are expensive, and, as a result, funding may take months or even years to accomplish. Begin your efforts for obtaining funds far in advance of when you need the new system to be operational.

More detailed information about public safety funding can be found in the *Report on Funding Mechanisms for Public Safety Radio Communications,* published by the Public Safety Wireless Network (PSWN) Program (see resources in appendix D).

Types of Funds

For most local agencies, the types of funds available fall into two general categories: local revenue funds and grants. Local revenue funds are obtained by local governments through local taxes (e.g., sales tax, property tax), user fees, and other user charges, plus through the issuing of debt instruments, like bonds. Grants are funds made available to local agencies from State and Federal government agencies, as well as from private sources (like foundations). Grants usually require you to submit a formal application to justify your request for funding.

Sources of Funds

The process you must go through to obtain funding for your project will vary depending on who owns the funds you want. This section focuses primarily on government sources of funds, not private sources.

Remember, to fully fund your project, you may need to get money from several different entities. In fact, many of the Federal grants *require* a certain amount of matching funding. Learning as much as possible about all the possible sources is in your best interest.

Federal Sources

Local governments receive public safety funding from Federal sources primarily through grants and cooperative agreements. A third source of funds for law enforcement has been asset forfeiture funds. (Most of the Federal public safety funding in the last decade has been primarily for law enforcement, with little specifically earmarked for fire and emergency medical services.) Grants fall into two categories: *block* (or *formula*) grants and *discretionary* (or categorical) grants.

Most public safety funding has come through the U.S. Department of Justice (DOJ). However, funds for infrastructure projects like communications are also possibly available through the U.S. Department of Commerce [National Telecommunications and Information Administration (NTIA)], the U.S. Department of Transportation (DOT), and the Federal Emergency Management Agency (FEMA).

A sample list of some of the programs that have provided funding recently, including the name of their funding and administering agency(s) and their matching funds requirements, is shown in table 3-1.

Table 3-1. Primary Federal Sources of Telecommunications/Technology Funding for Law Enforcement

Program Name	Type (Discre-tionary or Block)	Match Required?	Min. Match (%)	Fed. Source	Apply to	Contact
Local Law Enforcement Block Grants (LLEBG) Program	B	Yes	10%	DOJ-BJA	State	App.A
Edward Byrne Memorial State and Local Law Enforcement Assistance Program	B	Yes	15%	DOJ-BJA	State	App.A
State Identification Systems (SIS) Grants Program	B	No		DOJ-FBI/ BJA	State	Varies by State
Technology Opportunities Program (TOP, formerly TIIAP)	D	Yes	50%	DOC-NTIA	NTIA	App.B
Community Oriented Policing Services More (COPS MORE) Grant	D	Yes	15%	DOJ-COPS Office	COPS Office	COPS Office
Federal Emergency Management Agency (FEMA) Grants	D	Yes	50%	FEMA	FEMA	FEMA
State and Community Highway Safety Grants	B	Yes	20%	DOT	DOT	DOT

Block grants. Block grants are distributed by the Federal Government to States based on a statutory formula (which may take into account factors like population or crime rate). States then distribute their share of the block grant funds to local and State government agencies. The Federal Government issues broad guidelines about what type of things the funds can be used for, but the States process the actual applications.

The largest single formula grant source for law enforcement is the Edward Byrne Memorial State and Local Law Enforcement Assistance Program. Each State has an established office for assisting in the application for law enforcement-related block grants (at minimum to service the Byrne Program). The grant offices have various names within each State, although State planning agency is the most common. A list of the agency names and contact numbers for Byrne Program assistance in each State is given in appendix A.

In addition to administering the Byrne funds, these State agencies are often valuable resources for help in writing grants and for information about other funding sources.

A second block grant program, the Local Law Enforcement Block Grants (LLEBG) program, also has recently been a source of funds. If a jurisdiction is eligible for funding and completes an application, the Bureau of Justice Assistance (BJA) will make an award. The LLEBG program is not a competitive program.

Discretionary grants. Discretionary grants are usually focused on a specific purpose and are administered directly by agencies within the Federal Government. The rules for qualification, deadlines for application submittal, funds available, and format will be different for each type of grant and each agency administering the funds. Most require the local agency to provide some percentage of matching funds (see table 3-1).

The primary Federal funding agency for law enforcement grants is the Office of Justice Programs (OJP), within DOJ. The offices within OJP that make grants include BJA, Bureau of Justice Statistics (BJS), Corrections Program Office, Drug Courts Program Office, National Institute of Justice (NIJ), Office of Juvenile Justice and Delinquency Prevention (OJJDP), Office for Victims of Crime, and the Violence Against Women Office.

In recent years, a major source of law enforcement funding has been the Office of Community Oriented Policing Services (COPS), also within DOJ.

It is extremely important to follow all of the rules dictated by the funding agency regarding the application process. Each agency receives hundreds of applications for funding and will only consider applications that provide all of the necessary information and in the required format. Even if you have a great project idea, it will not get considered if you neglect to comply with the agency’s application instructions.

Federal asset forfeiture funds. Asset forfeiture programs are administered by two different Federal agencies: DOJ and the Department of the Treasury. Funds for these programs are obtained from forfeitures associated with the breaking of Federal law. Federal agencies have the authority to share fund revenues with any State and local law enforcement agencies that assisted in successful forfeiture cases.

If your agency has been involved in assisting a Federal agency and that case resulted in the seizing of assets, you should contact the Executive Office of Asset Forfeiture within either DOJ or Treasury for information about sharing of funds or property.

State Sources

The availability of State money to fund local public safety projects varies significantly from State to State (with the exception of the State-administered Federal block grants). Some States administer their own grant programs through a variety of different departments (e.g., Public Safety, Health, Human Services, Emergency Management, General Services, Business and Economic Development). The State planning agency administering the Byrne Program funds is the best place to start when inquiring into State sources of grant funding.

Sources other than traditional public safety-related State agencies are also worth exploring. For example, in Colorado, some police agencies have received Energy Impact Grants through the Division of Local Affairs. These are mitigation funds collected from oil and gas producers that are then returned to counties where petroleum extraction occurs. In this case, the funds are not public safety specific, but rather county specific.

Depending on the State, 911 and E911 surcharges are administered by the State and/or by the local government and may be available for communications projects. If you are unfamiliar with how 911 surcharges are administered in your State, contact either the national office or your State chapter of the National Emergency Number Association (NENA) (see resources in appendix D). NENA should be able to tell you who administers the funds for your agency and provide you with a contact name and number.

A number of States are planning or implementing statewide wireless communications projects. In some instances, these projects include providing access for local public safety agencies in addition to State agencies. Each State has funded these large-scale projects in various ways, ranging from State tax revenues to bonds to user fees. Unfortunately, each State administers these projects differently and through different departments. To find out if a project like this is under way in your State, try contacting the department or division responsible for telecommunications or the State law enforcement agency.

Local Sources

Local governments spend the revenues they collect in several ways. The largest percentage is through the general fund, which pays for the overall operational budget for the government. Funding requests made to a general fund must usually follow the budget preparation rules of the local government and will be competing against all other departments within that government entity.

In addition, the local government may have decided to incur long-term debt by issuing bonds, certificates of participation, or similar instruments. The money raised in this manner is used to pay for many multiple-year or high-cost projects. In some cases, a specific tax may be levied (kept separate from the general fund) that is earmarked to pay for certain capital improvement projects. (Remember, in some States, permission to issue debt or special taxes may require a vote of the citizens, which requires a ballot initiative and a significant amount of time and effort, with no guarantee of passage.)

Single agency versus multiple agencies. Over the past decade, increasingly agencies have been joining together to fund cooperative communications projects. The benefits of increased interoperability and reduced individual agency cost have overcome traditional resistance to sharing. Agencies have created intergovernmental agreements (IGAs), joint powers authorities (JPAs), nonprofit corporations, and other creative mechanisms for allowing the various agencies to contribute funds to a joint project.

Most agencies come up with some formula to determine the share of money that each must contribute. Formulas may be based on population, coverage area, number of transactions, number of units/officers, or any combination of these and other factors.

In addition to providing a mechanism for funneling local funds, a multiagency consortium often is able to obtain grant funds that a single agency might not. Many Federal grant programs look favorably on cooperative sharing of resources.

If you are considering creating a multiagency funding authority, contact several agencies that have participated in projects like this for suggestions on how to structure and fund your organization. They can give you valuable information on the time it takes to get all the various local governments to come to agreement, what has worked well for them, and what they would suggest you do differently.

“Selling” Your Need

Regardless of who you ask for funds, you must convince them that your project is necessary and that you will provide the most beneficial use of their dollars. The competition for funds is intense, and everyone believes that his or her needs are real. Getting the funds often depends more on your ability to present your needs in a businesslike and professional manner than on the need itself.

For example, the Technology Opportunities Program (TOP) of the Department of Commerce publishes extensive guidelines for preparing applications on its World Wide Web site (see resources in appendix D). In addition to a detailed budget, a TOP applicant must be able to clearly answer the following questions:

- ➡ What are the goals of the project?
- ➡ What are the anticipated outcomes?
- ➡ How will the proposed solution make a difference in the community?
- ➡ How many sites are there and where are they located?
- ➡ Which communities are to be served?
- ➡ What organizations are participating as project partners?
- ➡ What technologies are to be employed?
- ➡ What will users do with the technology?

The review team needs to know that the project you propose is worth doing and that your team can actually do it. The feasibility of the project will be judged based on your technical approach, the skills of your team members, and your budget estimates, schedule, and time line, as well as the long-term operational costs of the project. Failure to clearly define any of these items could be cause for rejection of your request.

Involve as many people as possible in reviewing your project request **before** you submit it to the funding agency. Have someone who is not directly involved in your project read it for clarity and purpose. Have your financial staff person review the budget for completeness and accuracy. Have a technical editor proofread it for punctuation and grammar. Have another agency that has been successful applying for funds make suggestions for improvement. Above all, make sure the proposal tells a complete and cohesive story and that no questions are left unanswered.

Remember, if you miss your chance with this proposal, you may have to wait a year to submit another. In the case of Federal grants, if the appropriations for that program are cut off next year, you may never get another chance.

Getting Help

This section identifies some of the Federal resources that you may find useful when looking for funding. Many more resources exist than are listed below. Appendix D lists a number of additional Web sites that may also be helpful.

For information about Federal grant programs in general:

➡ Get a copy of the *Catalog of Federal Domestic Assistance* through your local library for information on all Federal grant opportunities. The *Catalog* also can be ordered (for a fee) by calling 202–512–1800.

➡ Search the computerized database of grant programs, called FAPRS, maintained by the General Services Administration.

For information about DOJ programs specifically:

➡ Contact the DOJ Response Center at 800–421–6770.

➡ Contact the National Criminal Justice Reference Service (NCJRS) through its Web site at http://www.ncjrs.org or via e-mail at askncjrs@ncjrs.org.

➡ Contact the BJA Clearinghouse at 800–688–4252. (NCJRS, cited above, is the online version of the Clearinghouse.)

For information about DOJ block grant programs administered by each State:

➡ Contact the applicable State planning agency given in appendix A.

For information about TOP grant programs:

➡ Contact the applicable NTIA State Single Point of Contact (SPOC) given in appendix B.

To automatically receive notice about all solicitations sent out by DOJ:

➡ Ask NJCRS (see above for contact information) to put you on its mailing list for grant proposal solicitations.

➡ Check the postings on the BJA home page at http://www.ojp.usdoj.gov/BJA.

For help writing a grant:

➡ For law enforcement officials, the FBI's National Academy Program offers a noncredit course on grant program development and budgetary issues. Contact the FBI for more information.

➡ Contact other agencies that have successfully applied for the grant you are interested in. Ask them for copies of their grant proposals. Lists of successful applicants are found on many of the Federal Web sites, in particular at http://www.ncjrs.org

Additional information sources are identified in the resources in appendix D.

Chapter 4

Buying What You Need

Once funding has been secured, the purchasing process can begin. This section discusses the primary ways that communications systems have been purchased but does not attempt to itemize every variation that has been used.

How to Buy

Most government agencies have specific purchasing rules and regulations that must be followed for purchases to be legal. You should consult with the staff from your purchasing division or department to determine the rules that govern your agency.

Competitive Procurement

A competitive procurement usually involves the development of purchasing specifications by the local agency and then issuing of a Request for Quotation (RFQ) and/or a Request for Proposal (RFP). Multiple vendors respond to the RFQ with a bid (or to the RFP with a proposal) to provide what the agency has requested. A competitive procurement is designed to encourage competition among vendors to encourage fair pricing.

An RFQ is generally used to purchase commodities, which can be easily described and for which there are several suppliers. Most awards that result from RFQs are based on low bid.

An RFP is used for purchasing more complex items, like communications systems, for which a number of variables besides price may influence an award decision. For example, other variables could include maintenance hours, financial stability of the company, references from other clients, and ease of use.

Because it is the most common method for purchasing a communications system, the competitive procurement process using an RFP is detailed in a section below.

Noncompetitive Procurement

Local governments can contract for services in many cases without going out to bid. Check with your city/county purchasing department to see if there are any clauses in your policies and procedures that would work to your benefit. Two common examples that are used with communications are *sole source procurement* and *contract for operational services.*

Sole source procurement. In a sole source procurement, goods and/or services can be purchased from a vendor that has previously been awarded a contract, usually through a competitive bid process. The reasoning is that if that vendor is the "sole source" for additional items that are compatible with items already supplied, then another competitive procurement does not need to be conducted. For example, if you had purchased computer software from a vendor and now decide that you want to upgrade to a newer version of its software, and since it is the only one that makes that software, you could issue that vendor a purchase order without going to bid.

Each jurisdiction deals with the issue of sole source procurement differently. Some allow sole sourcing to vendors without a previous competitive procurement. Others do not allow it at all. If there is something you want to consider purchasing by sole source, you should check with your local purchasing manager *before* you issue any purchase orders to make sure you are in compliance with local ordinances.

Contract for operational services. Agencies contract for many types of operational services, like cellular telephone service and pager service. Many purchasing divisions treat service contracts differently than they treat contracts for purchase. You may only need to show that you have sufficient funds in your budget to pay for the service you want. In some cases, you may not even have to prove that since the belief is that you will cancel the service if you have no more money in your budget.

Some agencies have purchased mobile data cellular service [e.g., Cellular Digital Packet Data (CDPD) service] through noncompetitive service agreements and, thus, have completely avoided the competitive procurement of radio infrastructure equipment.

As always, you should confirm with purchasing that there are no restrictions to your contracting for services.

Cooperative Purchasing

Cooperative purchasing refers to the practice of buying from another agency's competitive procurement. The most common type is the ability of a local agency to buy from the State's price agreement list. State governments routinely solicit bids for thousands of commonly used items, like computers and printers, at fixed prices. Vendors promise to supply all of the items the State wants at that fixed price for a fixed period, frequently 1 year. Local governments can buy from these awards throughout the year at volume discount prices, usually without going through their own bidding process.

Check with your agency's purchasing manager to determine whether your State allows you to purchase items from its awards. Or contact the State purchasing division directly to see if it supports this type of cooperative purchasing.

Leasing

Leasing is not really a type of procurement, but rather is a way to pay once a procurement has been made. One of the above procurement methods would be used to select a vendor and determine a price. Once that was done, the local government could decide to finance the purchase and pay for it over a period of months or years, rather than purchase the equipment outright.

Leasing can be advantageous in those cases where you do not receive all of your funding at one time. For example, if sales tax revenues are funding your project, the revenues are spread out over a number of years. In that case, it might make sense to also spread your payments out over a similar number of years. The total cost of the purchase will be higher (because of interest charges), but you will get use of the system sooner than if you wait until all of the revenues are received.

With most government leases, the government owns the equipment upon contract completion. The equipment can then be traded or upgraded as technology improves or requirements change.

Leasing companies are generally willing to work with your agency to structure the lease to conform to your budget, tax, cash flow, delivery, or regulatory restraints. Because of the number of companies now offering leasing to government agencies, your purchasing agent may decide to ask a number of companies to bid on providing the lease, thus ensuring that you receive the most favorable finance rate.

Outsourcing

Outsourcing is one of the newer methods of procurement, at least at the local government level. Outsourcing refers to hiring an outside company to perform services traditionally performed by agency staff. The level of service can vary, from just providing the people to operate agency equipment to contracting for provision of people and equipment.

For example, an agency in Pennsylvania outsourced its entire emergency communications center. The vendor supplied the facility where the communications center was located, the people to manage and staff the center, the computer-aided dispatch system, the telephone equipment, and all other aspects of the center. The agency estimated that it would actually save money over the 10-year course of the contract by *not* operating the center itself.

Because relatively few governments have done this, you may want to talk to companies in your area that have outsourced services. While somewhat new to local government, it has been used for a number of years in corporate settings, with significant cost savings.

Request for Information (RFI)

Technically, this is not a procurement. However, it can allow you to gather information in a structured manner that will allow you to determine what products and services are currently on the market and their associated costs. Generally, the vendors provide only estimates of costs, but these are extremely useful in creating your budget.

An RFI usually describes the scope of the project, your projected time line, and any other descriptive information about the project. Vendors are asked to provide information about their suggested solution, with supporting product material and cost estimate information.

In some cases, vendors have been required to respond to an RFI to be eligible to move to the next step and receive the RFP.

Competitive Procurement (RFP)

The goal of this section is to provide additional details about competitive procurements using an RFP. It is not intended to cover every aspect of the procurement process, but rather is intended to give you an overview of what is involved. Specific requirements for the RFP should be requested from your local purchasing manager.

Request for Proposal (RFP)

As mentioned previously, an RFP is used for purchasing more complex items for which a number of variables besides price are important to the purchasing decision (see figure 4-1).

RFP Process

The following steps are involved in the RFP process (and are summarized in figure 4-1).

Develop the RFP. There are three main sections of an RFP: the instructions to proposers, the terms and conditions of purchase, and the technical specifications. Templates for the first two are generally provided to you by your purchasing agent. You may then need to add, delete, or modify portions of these as appropriate to the needs of your project.

The development of the technical specifications is usually the responsibility of the project team. The specification must be clear and comprehensive so that both you and the vendor know precisely what is wanted and what is expected of each party. Avoid over specifying, as it can limit the number of vendors that respond and, thus, limit your options.

You need to make sure that your RFP, at minimum, does each of the following:

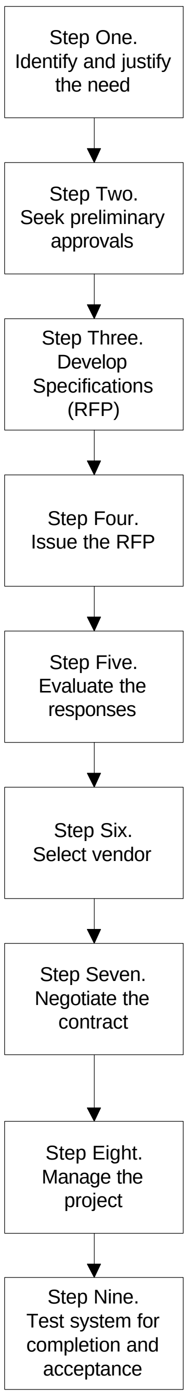
➡ Describes the problem being addressed.

➡ Describes the existing environment (e.g., existing equipment, operational procedures, agency standards, constraints).

➡ Describes the required project outcomes.

➡ Describes the scope and standard of service required in ALL areas (i.e., user functionality, system response times, delivery schedule, service levels, training).

Figure 4-1. Steps in the RFP Process



- ➡ Identifies mandatory features and desirable features.
- ➡ Identifies the key contractual terms and conditions (e.g., items that the agency is not willing to negotiate).
- ➡ Identifies criteria for acceptance and contract completion.

Obtain copies of RFPs for similar projects from other agencies and use these as a template for building your own specifications. However, never copy another agency's RFP verbatim. If you do not understand why certain terms or requirements were included by the agency in its RFP, ask the agency. It may have had certain requirements that do not apply to your project and that you should not include. You may have other requirements the agency did not need that you will want to add.

Remember, however, that a template is simply a starting point. It does not eliminate all of the work needed to create a thorough and complete RFP that best represents the needs of your project. If you are lucky, it just reduces the work somewhat and helps ensure that nothing is forgotten.

Once the RFP is written, have your team review it for completeness. Include members of your legal and purchasing departments as part of the review team. Make all necessary modifications before releasing the RFP. It is easier and better to delay issuing the RFP while you make corrections than to have to issue addenda during the procurement process.

Issue the RFP. Once the RFP has been completed and approved by your team, it is usually the responsibility of the purchasing department to issue it. The department has a standard set of procedures to follow that ensures that all of the legal mandates are met.

A period of time is often allowed within which potential vendors may submit questions. You need to be prepared to answer these questions in a timely manner and also to make sure that all potential vendors receive copies of the questions and responses to ensure impartiality. Many agencies host a vendors' conference to allow vendors to ask questions all at once and also to allow the vendors to inspect your site. This may reduce the number of written questions to which you are required to respond.

Allow vendors enough time to prepare a thorough response to your RFP. Depending on the complexity of the project, a period of from 1 to 2 months is common.

Proposals must be submitted by the date and time indicated in the RFP. Be sure to request enough copies for all evaluation team members. If a vendor submits a proposal after that time, its proposal should not be opened or included in the evaluation process.

Once the proposals are received and verified by purchasing, distribute copies to your evaluation team, which will include your implementation team as well as others with a vested interest in the project.

Evaluate responses. When evaluating the responses to the RFP, you must consider a number of items:

- ➡ **Compliance.** Does the proposal comply with the required specifications in the RFP? If it does not, eliminate the proposal from further consideration.
- ➡ **Value.** Value is more than just price. It may include all or some of the following: purchase price, quality, warranties, maintenance costs, training, service, response time, reliability, company stability, delivery time, and contract terms and conditions, among others.
- ➡ **Total Life Cycle Costs.** How much will the system cost over its expected life. In other words, if you expect the system to last 10 years, the life cycle cost would include the initial purchase price PLUS all operating and maintenance costs incurred over the entire 10 years. A system that has a low initial purchase price may have high maintenance costs that, over time, may cause its total life cycle cost to exceed that of a vendor with a higher initial purchase price.
- ➡ **Company References.** Talk to recent clients who have made similar purchases from the vendors for feedback on performance. Talking to several people from each client site will give you a more rounded impression of each vendor's performance.

Evaluate the proposals against evaluation criteria that were defined *before* the proposals were received. The goal is to select the proposal that best meets the defined needs and to determine whether the vendor has the ability to perform the work.

Read each proposal thoroughly. Use a standard evaluation format (e.g., a spreadsheet or written form) to help you compare responses of vendors more easily. Keep copies of the results.

Have your agency's purchasing and/or legal staff review the terms and conditions of the proposal to ensure that the vendor has not counter proposed any terms that would be unacceptable to your agency.

The entire evaluation process should be clear, fair, and equitable. Treating all vendors the same and keeping good records of the results of the evaluations will help ensure that there is no basis for a protest of your selection.

Select vendor. If a single best vendor emerges from the above evaluation process, you can move on to the contract negotiation phase of the process. However, it is more likely that there will be two or three vendors who appear comparable on paper (the “short list”). Before a clear winner can be selected, additional in-person demonstrations and/or interviews may be required with each of the short-listed vendors.

As a result of the demonstrations and/or interviews, each vendor may be asked to submit a best and final offer that allows an “apples to apples” comparison of the proposals and their value.

At this time, you should evaluate each company’s financial stability as well, through bank references, credit reports, public financial records (if a public company), and other similar checks. Get help from experienced financial experts, either inside your agency or outside it, to ensure that you obtain the right information and that it is correctly interpreted.

Another important consideration is the company’s ability to perform the work. In other words, does it have enough staff to do your project as well as the other projects to which it is already committed. Check to see how many concurrent projects the company is working on. Also check to see if it has adequate customer support staff to assist you with maintenance problems after the project has been installed.

Ultimately, the final selection should represent the best value for the money, from a financially stable, responsive, and well-respected company.

The unsuccessful vendors should be notified in writing once a selection has been made. However, the finalists should not be released from their obligation to perform until a final contract has been signed between the selected vendor and your agency. In the event that you are unable to successfully negotiate a contract with your selected vendor, you may wish to initiate negotiations with another of the finalists.

Negotiate contract. A written contract is mandatory. Both parties will benefit by having a document that clearly identifies each other’s obligations.

The contract negotiation should begin as soon as possible after selection of the final vendor. The negotiations should be conducted between individuals from each of the parties who have the authority to make commitments on behalf of their agency or company. Otherwise, a great deal of time and effort can be expended during the negotiation process only to find out that the “powers that be” will not approve the resulting contract.

Your negotiators should have skills and experience in negotiating complex, high-technology contracts. If you do not have such expertise within your agency, seek help from recognized experts within other departments/agencies.

A copy of your agency’s Standard Contract Terms and Conditions should have been included in the RFP and should serve as the basis for negotiating a final contract. (It is usually not in the best interests of the agency to use the vendor’s standard contract terms and conditions; however, there may be circumstances when this is the best option available.)

In addition to legal terms and conditions, every contract should include a project schedule. This schedule should set clear, identifiable milestones for completion of each phase of the project. A milestone should be easy to measure and/or to determine that it has been completed.

The contract should also include a specific payment schedule, which clearly identifies when and under what circumstances payments will be made. As much as possible, payments should be tied to project milestones, with fixed-price amounts itemized. A certain percentage of the total contract price should be retained until the entire project is completed to ensure that all work has been completed to your agency's satisfaction.

The contract should specify how requests for changes in scope of work will be handled and who is authorized to request such changes. The contract should require that all changes to the scope of a contract be in writing (verbal authorization is not sufficient) to be binding. In addition, it is important to specify how any changes in the project cost, which may be associated with scope changes, will be handled.

Your agency's purchasing adviser and legal advisor should **always** be involved in reviewing any contract documents before they are finalized. Otherwise, the modifications made during the negotiation process may not be in compliance with existing governmental laws, rules, and regulations.

Ensure that the final contract is signed by the individuals from each party who are legally authorized to do so. Otherwise, the contract may be ruled invalid.

Manage the project. Managing the installation is one of the most important aspects of a successful project. Once the contract is signed, it is critical to monitor vendor performance, the contract terms, and the payments.

The project manager must ensure that the agency is getting what it asked for and that required milestones are met. Payments should only be made if milestones are completed as promised. However, payments should not be unreasonably withheld either. Ensure that payments are made on time for work properly performed.

One key to successful project management is open and frequent communications between the agency's project manager and the vendor's project manager. Raise questions or concerns as soon as they arise; don't wait for the next scheduled meeting. Waiting could cause a delay in your implementation.

Project management is a subject upon which numerous books have been written and for which many classes are taught. It is beyond the scope of this guidebook to cover all aspects of good project management. A number of excellent project management software programs are available for helping with the planning, scheduling, and recording of the project tasks. Many include guidebooks on project management with the software.

Acceptance testing. The specifications should have indicated the system parameters to be tested and accepted. A thorough test plan should be submitted by the vendor. Tests should be run and witnessed by the agency *before* the system is turned over to the agency. All deficiencies should be corrected *before* final acceptance and final payment.

PART 2

WIRELESS COMMUNICATIONS TECHNOLOGY

Chapter 5

Voice Versus Data

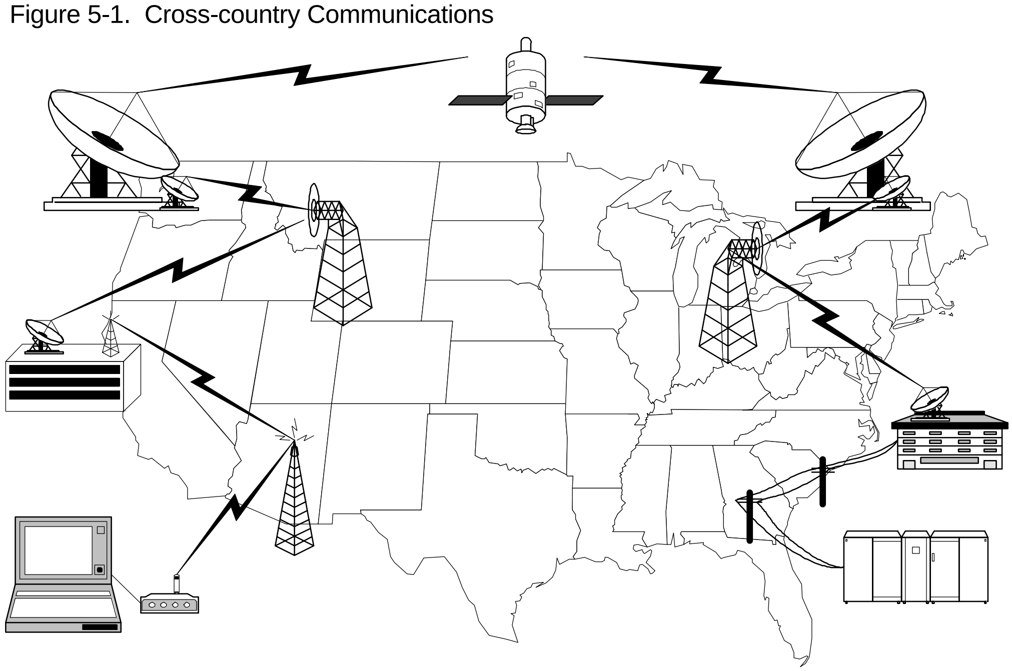
Voice Versus Data

Two types of communications, voice and data, have been traditionally sent over public safety radio systems. Voice communications includes all audio transmissions, which start as voice and end as voice.

Data communications involves the transmission of data from one computer to another, through one or more communications channels (standard telephone lines, radios, etc.). When data are sent over long distances, it is likely that a number of different types of communications channels will be used.

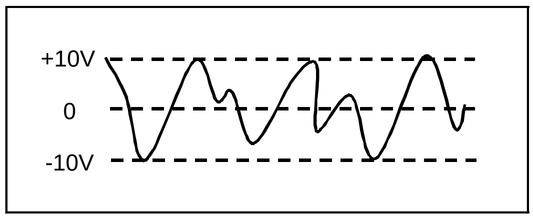
For example, figure 5-1 shows the various communications methods involved in sending data from an agency in California to an agency in Florida.

Figure 5-1. Cross-country Communications



Voice normally occurs as an analog signal. In other words, the signal may vary continuously over a specific range of values. In figure 5-2, the voltage of the analog signal may take on any value between -10 volts and +10 volts.

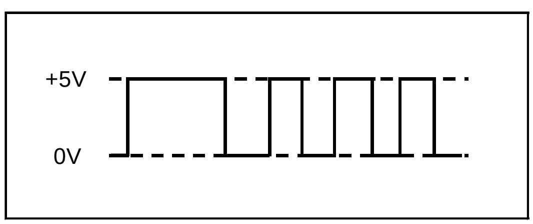
Figure 5-2. Analog Signal



Computers store data electronically. Circuits in the computer can detect the presence or absence of electronic impulses. A bit (binary digit) is the smallest piece of information contained in a data transmission and can only represent one of two values: a zero (0) or a one (1). Combinations of bits are strung together to represent numbers, letters, and other special characters.

Data can also be represented as a digital signal, which can only assume discrete values. For example, in figure 5-3 below, the voltage of the digital signal may only take on the values of either 0 volts ("off" or zero) or +5 volts ("on" or one).

Figure 5-3. Digital Signal



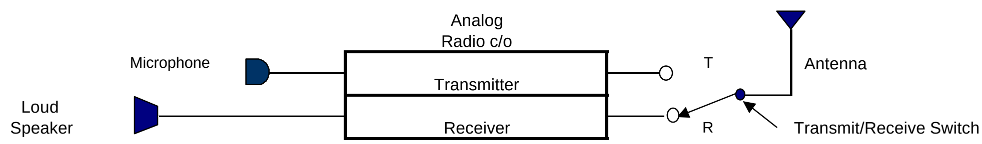
Analog Versus Digital

Voice and data can both be packaged and transmitted using either analog or digital signals. This section discusses the differences between using an analog transmission method and a digital transmission method.

Analog Radio Systems

Analog radio systems continuously transmit radio waves that are usually modulated by a voice. A typical analog voice radio consists of a transmitter and receiver (figure 5-4).

Figure 5-4.Block Diagram of a Typical Radio System



An analog system may also carry data. However, the data, which are in digital form of binary digits, or bits (i.e., ones and zeros), must first be converted to an analog signal. A modem (modulate/demodulate unit) is used to convert the ones and zeros into two analog tones representing either a one or a zero. When the analog data arrive at the receiver, they are converted back to digital form again using another modem.

Figure 5-5. Block Diagram of an Analog Cellular Phone with a Laptop Computer

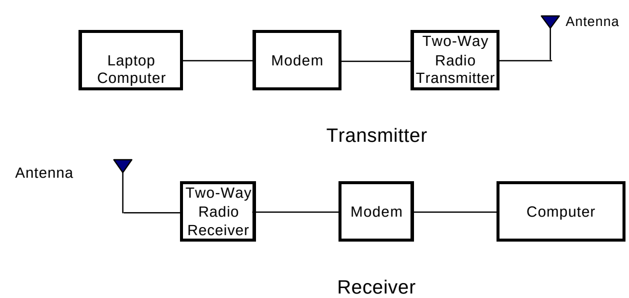


Figure 5-5 shows a laptop computer connection through a modem to a typical two-way FM radio. The laptop generates data as ones and zeros that are converted via the modem to analog tones that go into the radio transmitter. Once received, the detected tones pass through a second modem that converts the signal back to digital data and sends them on to another computer for additional processing (e.g, display, printing, query to NCIC).

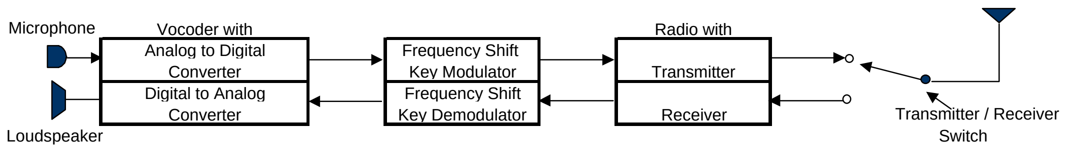
Digital Radio Systems

People cannot usually understand digital signals. Our senses are analog oriented and can only respond to continuous signals or impressions. Therefore, we must hear voice transmissions on a loudspeaker or a set of headphones and see visual signals, on either a video monitor or a printer, as words and pictures.

Voice transmissions may be sent over digital radio systems by sampling the voice frequency and then changing the sampled information to ones and zeros to modulate the carrier. This is done using a circuit called a voice coder, or "vocoder." At the receiver, the process is reversed to convert the digital voice samples back into analog voice.

A diagram of a typical digital voice radio system is shown in figure 5-6.

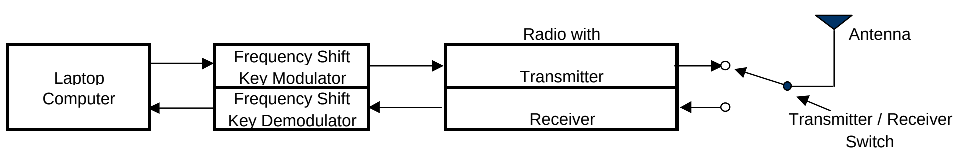
Figure 5-6. Block Diagram of a Voice Modulated Digital Radio System



A digital radio system transmits data directly, by digitally modulating a carrier. One simple method of modulation is to change the carrier frequency by shifting it different amounts for each type of bit. (This is called *frequency shift keying*, or FSK.) The receiver then receives the signal as a zero or as a one and re-creates the original signal.

A simplified digital radio is shown in figure 5-7. The ones and zeros are detected and regenerated at a receiver for use in a computer.

Figure 5-7. Block Diagram of a Typical Digital Radio System



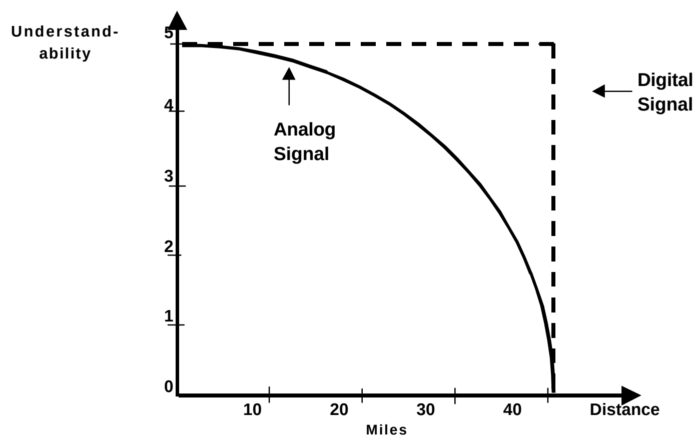
Transmission Differences

Analog and digital radio systems have vastly different transmission characteristics. As you move away from an analog radio transmitting site, the signal quality decreases gradually while noise levels increase. The signal becomes increasingly more difficult to understand until it can no longer be heard as anything other than static.

A digital signal has fairly consistent quality as it moves away from the transmitter until it reaches a threshold distance. At this point, the signal quality takes a nose dive and can no longer be understood.

A comparison of the transmission differences between analog and digital signals is shown in figure 5-8.

Figure 5-8. An Analog Versus Digital Signal



Chapter 6

Characteristics of Radio Systems

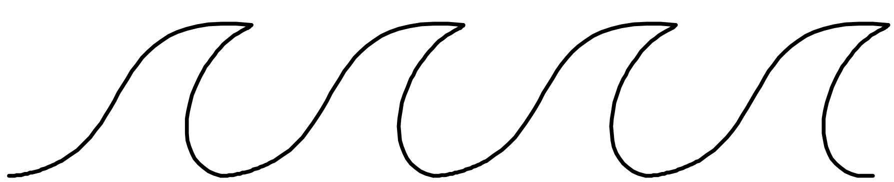
Understanding Radio Terms

Radio technology is full of confusing terms that come straight from a physics book. Sometimes when you ask a radio engineer a question, you even get an answer that is a formula. The authors have tried to simplify the terms as much as possible to allow you to get a good handle on the concepts. The goal in this section is not to turn you into radio experts, but, it is hoped that you'll be able to understand the experts a little better when they talk to you.

Wave

The basic building block of radio communications is the radio wave. Like waves on the ocean, a radio wave is merely a stream of repeating peaks and valleys (figure 6-1).

Figure 6-1. Ocean Waves



One big difference between ocean waves and radio waves is that ocean waves are visible, while radio waves are not. People can see how far apart or how high the peaks are on the ocean. Radio waves have those same characteristics; people just cannot see them.

Wavelength

The length of a wave is measured from one point to its next corresponding point. In other words, the wavelength could be the distance from one peak to the next peak or from one valley to the next valley and so on, as shown in figure 6-2.

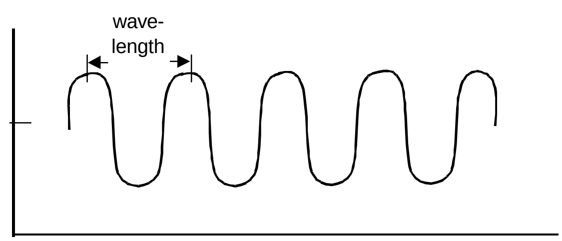


Figure 6-2. Wavelength

In radio terms, a *short* wavelength would mean that the peaks are relatively close together. A *long* wavelength would mean that the peaks are relatively far apart.

Cycle

The entire pattern of the wave, before it begins to repeat itself, is called a cycle. A repeating pattern of cycles that make up a wave is shown in figure 6-3.

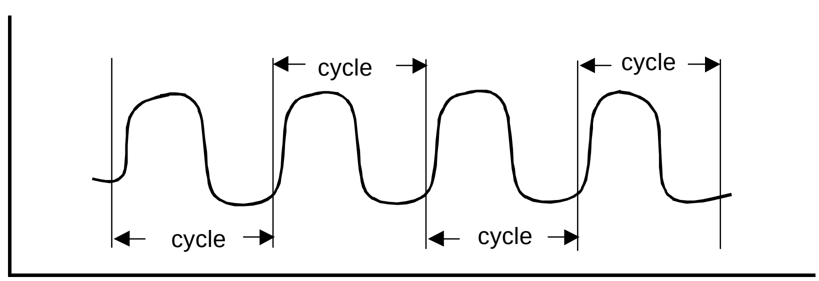


Figure 6-3. Cycles

Frequency

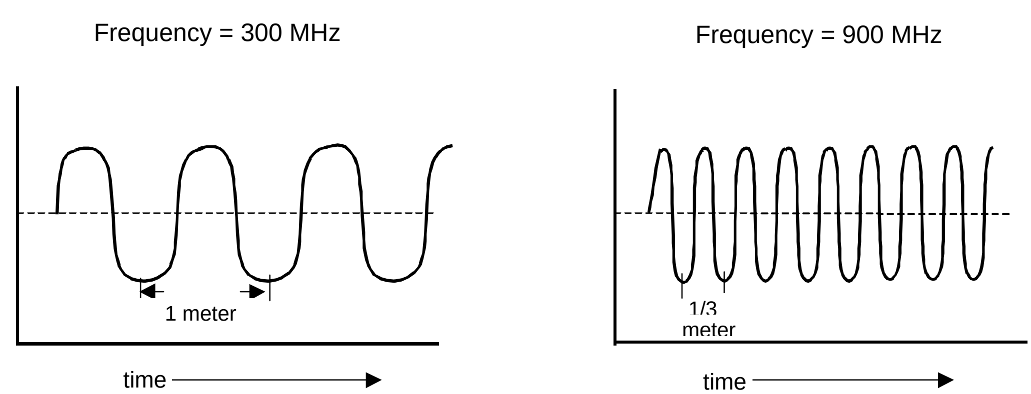
Cycles repeat over time. The fact that they do is the basis for one of the most important terms in radio communications: *frequency*. Frequency is defined as the number of cycles that occur each second.

When they talk about frequency, radio engineers use a shorthand term for “cycles per second,” which they call “Hertz.” (The word Hertz is usually shortened to “Hz” when written.) Both terms mean the same thing. So, if you were told the frequency of the wave was 10 Hertz, you would know that meant 10 cycles per second.

Thousands of radio wave cycles usually repeat themselves each second, so engineers have adopted the practice of writing kilohertz (shortened to KHz), which means 1,000 cycles per second, megahertz (MHz), which means 1 million cycles per second, or gigahertz (GHz), which means 1 billion cycles per second, when they refer to radio frequency. Thus, 10 million cycles per second can also be written as 10 MHz.

Frequency and wavelength are inversely related. In other words, the higher the frequency, the shorter the wavelength, and conversely, the lower the frequency, the longer the wavelength. These relationships are illustrated in figure 6-4. At 300 MHz (300 million cycles per second), the distance between the peaks of the wave is 1 meter. When the frequency is tripled to 900 MHz (900 million cycles per second), the wavelength is reduced to 1/3 meter (1/3 of the previous distance between the peaks).

Figure 6-4. Inverse Relationship Between Frequency and Wavelength



At extremely high frequencies (above 30 GHz), the distance between the peaks of the wave becomes so small (1 centimeter or less) that a raindrop would not fit between them. In fact, at these extremely high frequencies, it is possible for rainy weather to disrupt the wave and distort or completely block the resulting signal.

Spectrum and Bands

The complete range of possible frequencies that are now or could be used for radio communications is called the *spectrum*. The audible frequency range is usually considered to range from 20 to 18,000 cycles per second or Hertz. For practical purposes, the useful radio spectrum ranges from approximately 30 KHz up to more than 300 GHz.

Radio professionals often discuss frequencies by grouping them into ranges, which are called *bands*. The bands are often referred to by names like HF (high frequency), VHF (very high frequency), UHF (ultra-high frequency), SHF (superhigh frequency), EHF (extremely high frequency), and infrared.

Public safety bands. Two of the radio frequency bands are of particular interest to law enforcement agencies installing their own mobile radio systems. These are the VHF and UHF bands, whose ranges are designated as VHF 30 - 300 MHz and UHF 300 - 3,000 MHz.

Specific bands and frequencies used for public safety wireless communications are shown in table 6-1.

Table 6-1. Public Safety Bands and Frequencies

Public Safety Band Name	Frequencies (MHz)	Channel Separation (KHz)[1]	Services
VHF (low band)	25 - 50 72 - 76	20	Mixed base and mobile Mixed base and mobile
VHF (high band)	150 - 174	15	Mixed base and mobile
UHF	450 - 512	30	Mixed base and mobile
UHF (750/800/900)	750/800/900	25/30	Mixed base, mobile, and cellular
2 GHz	2,000	10/20/30 MHz	Personal Communications Services

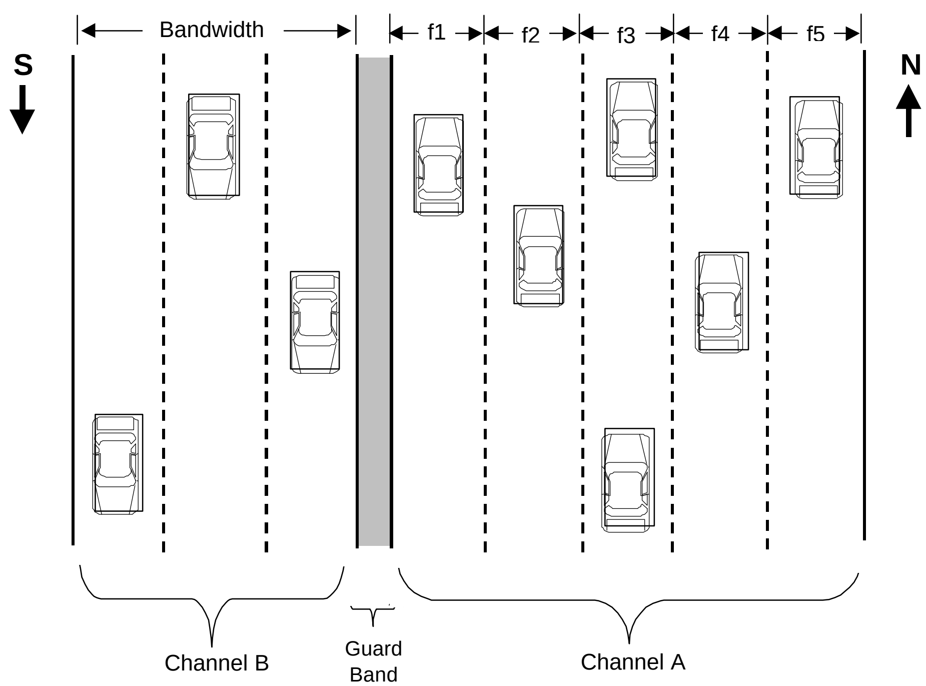
[1] This is the separation most of the time. New equipment below 512 MHz has separations of 12.5 or 15 KHz until 2006, when the separations will be halved again (i.e., in the 150 MHz band, the bandwidth will be 7.5 KHz in 2006).

Channels

The Federal Communications Commission (FCC) arbitrarily groups frequencies into categories they call *channels*. When the FCC licenses a channel to you, it specifically identifies the center frequency (sometimes called carrier frequency) for that channel. This central frequency is the main frequency for carrying the information to be transmitted. Thus, the radio information is transmitted over the several frequencies contained within a single channel. The more frequencies in a channel, the greater its width (called *bandwidth*), and the greater the amount of information it can carry.

For example, if a channel were similar to a multilane highway, then the frequencies would be like all the lanes of the highway that travel in the same direction, say northbound (see figure 6-5). The information traveling over the channel is like the cars that travel on the highway. The width of the highway (i.e., the bandwidth) will equal the total width of all the lanes combined. Therefore, the more lanes on the highway, the more cars that highway can handle. The center lane on the highway would be similar to the center or carrier frequency.

Figure 6-5. Channels in a Wireless "Highway"



In a similar way, a second channel could be compared to the other side of the highway where all of the lanes travel in a different direction (southbound). A concrete barrier or median strip exists to separate the northbound lanes from the southbound lanes. A similar nonoverlap space exists between channels and is called the *guard band*.

One more note: In our example, the northbound highway has five lanes, while the southbound highway has only three. Like highways, not all channels need be the same width, even if they occur in the same band.

As mentioned before, generally, the wider the bandwidth, the more information may be transmitted. However, with microprocessors and sophisticated software techniques, more information can now be sent through less bandwidth than was possible just a decade ago (sort of like car pooling). As a result, *spectrum efficiency* has improved.

Mobile Radio System Frequencies

The FCC has assigned frequencies so that there are 30 KHz between channels in the UHF band. In other words, a 900 MHz frequency assignment (the center frequency) means that the information transmission falls between 899,985 KHz and 900,015 KHz (i.e., 15 KHz on either side of the center frequency).

In its goal to promote the efficient use of the spectrum, the FCC is changing most of the bandwidths of radio channels below 512 MHz in a process it calls “refarming.” It is presently reducing channel bandwidths in half and will reduce the bandwidths in half again in the year 2006. In other words, the first step is to reduce the channel bandwidth from 30 KHz to 15 KHz, then to 7.5 KHz (or, for a 25 KHz VHF channel bandwidth, to 12.5 KHz, and then to 6.25 KHz).

Frequencies covering TV channels 60–69 have been reallocated from television to private use and public safety. Public safety’s portion, 24 MHz, will include frequencies from 764 to 776 MHz and from 794 to 806 MHz. No band plans have been released by the FCC designating specific uses (also see discussion in chapter 9). The nonpublic safety frequencies being reallocated will be auctioned off by the FCC.

Frequency Selection Considerations

Coverage. In general, the lower the frequency, the better the coverage for a given power level. VHF low band has the best coverage for a given *effective radiated power* (ERP). This is because the attenuation increases or the signal level decreases as a function of ($1/\text{frequency}^2$). This is why UHF TV stations are permitted to transmit with ERPs of 5 megawatts, compared with VHF TV stations that transmit with 100 to 300 kilowatts. This equalizes the received signals at a far distance.

Building penetration. UHF frequencies with shorter wavelengths have better building penetration through windows than do VHF frequencies.

Skip. At VHF low band, stations can experience “skip” (the radio wave reflects from the ionosphere during the height of the sunspot cycle), often causing so much interference that local communications cannot be carried out.

Noise. Natural and manmade noise is worse the lower the frequency. Higher bands experience much less noise interference.

Antenna size. The lower the frequency, the larger the antennas for a given amount of gain. (Reasons for this are discussed in the upcoming section on antennas.)

In summary, selection of the frequency band of operation is dependent upon the desired system characteristics. Table 6-2 summarizes the above-mentioned characteristics.

Table 6-2. Technical Frequency Selection Criteria			
Parameter/Band	**Low Band VHF**	**High Band VHF**	**UHF**
Propagation[1]	Very good	Good	Poor
Building penetration[2]	Poor	Poor	Better
Skip interference	Very susceptible	Little skip	No skip
Manmade noise	High noise	Less noise	Lowest noise
Antenna size[3]	Large	Smaller	Smallest

[1] For a given ERP (signal attenuation is proportional to $1/f^2$).

[2] For a dense (concrete) building with windows.

[3] For a given amount of antenna gain.

Transmitters and Receivers

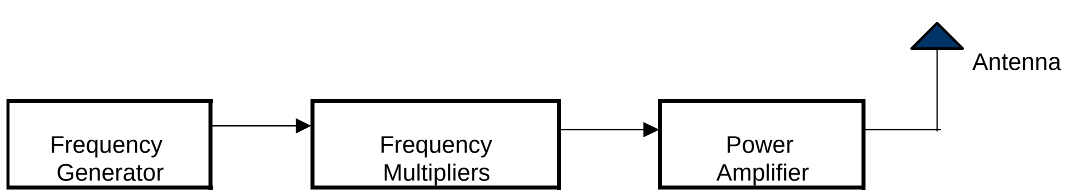
Base, mobiles, and handheld radios consist of components called *transmitters* and *receivers*. In some cases the circuitry is used for both transmitting and receiving so a radio is said to be a *transceiver*.

Transmitters

A transmitter generates a radio wave or signal. A diagram of a simple transmitter is shown in figure 6-6.

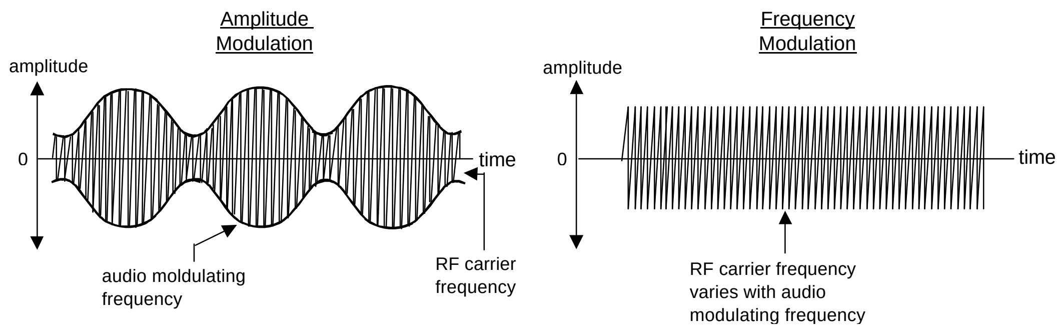
The frequency generating component is called an *oscillator*. *Frequency multipliers* multiply the frequency up to the final output frequency. A power *amplifier* increases the power of the signal to obtain the necessary power output to the antenna.

Figure 6-6. A Simplified Radio Transmitter



The output frequency is a continuous wave (CW) called a carrier. Intelligence is added to the transmitter by varying the *amplitude* of the carrier (amplitude modulation or AM) or by varying the frequency of the carrier (frequency or phase modulation or FM). Figure 6-7 shows the difference between amplitude and frequency modulation.

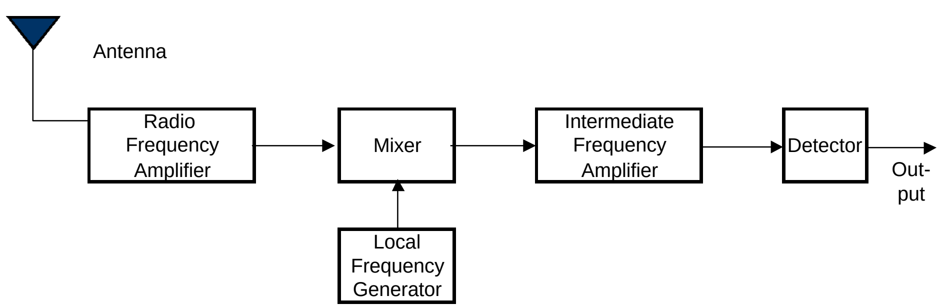
Figure 6-7. Comparison of Amplitude versus Frequency Modulation



Receivers

The receiver is the opposite of the transmitter. It receives the modulated carrier, processes it, and sends it to a detector section, which strips off the modulation signal from the carrier to restore the original intelligence. A diagram for a simple receiver is shown in figure 6-8.

Figure 6-8. A Simplified Radio Receiver



Radio systems are generally designed for AM or FM. Voice transmission is produced using a microphone at the input of the transmitter and a loud speaker at the output of the receiver. The signals are usually analog, or continuous, signals.

Data are transmitted using binary signals. One simple method of transmitting a binary signal uses frequency shift keying (FSK). A zero is represented by transmitting a particular carrier frequency, and a one is represented by shifting the carrier frequency to a different frequency (usually less than 1,000 Hz). The receiver interprets the ones and zeroes and reconstructs the binary data stream.

This is just one simple scheme for transmitting data. Most of today's systems use much more complex methods to maximize spectrum efficiency.

As stated elsewhere in this book, human beings cannot directly interpret most digital signals. People live in an analog world, one with continuous audio frequency loud speakers, printers, television, or computer screens. The exception to this is the use of Morse Code, which consists of ones and zeros. Skillful Morse Code operators can interpret the dots and dashes in their heads into letters and numbers. For digital radio, however, a digital-to-analog converter is necessary to communicate with human beings.

Note that figure 6-8 is greatly simplified. All communications receivers have squelch circuits before the audio circuits, which keeps the output off when there is no signal (so that you do not have to listen to noise) and passes the detected signal through when the correctly coded signal is received. Several different types of squelch are used. Commonly used squelch schemes are continuous-tone-coded squelch and digital squelch.

Antennas

An *antenna* allows a radio transmitter to send energy into space and a receiver, to pick up energy from space. The higher an antenna is above the ground, the larger the coverage of the radio signal.

The fundamental antenna is the *dipole*, which consists of a wire or rigid metal rod. A dipole's length is set to be approximately one-half the wavelength of the carrier frequency. Thus, a 300 MHz carrier, with a wavelength of 1 meter, would need to use a dipole that is ½ meter long. Similarly, the dipole for a 900-MHz carrier, whose wavelength is 1/3 meter, would be 1/6 meter long (approximately 6e inches).

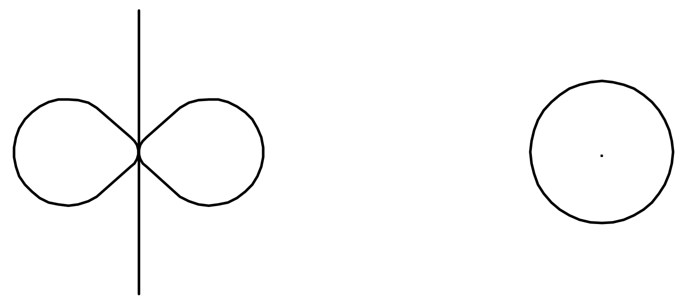
Assuming the wire is vertical, the three-dimensional radiation pattern is *omnidirectional* around the wire in the horizontal plane and is donut shaped in the vertical plane, as shown in figure 6-9. (Omnidirectional means that the same amount of radiation can be measured the entire way around, at any given cross-section of the donut.)

If the antenna is vertical to the earth's surface, its electric field will be vertical, and the antenna is said to have vertical *polarization*. If the antenna is horizontal and the electric field is parallel to the earth's surface, the polarization is horizontal. Almost all mobile operations use vertical polarization.

Gain

By concentrating the energy from or to a dipole antenna in a particular direction, you can increase the effective transmitted power toward that direction and increase the received signal strength from that direction. This is important for two reasons: 1) you may use less power to transmit a signal for the same signal level at a receiving site and 2) interfering signals at other directions will decrease in level causing less radio frequency interference for you.

Figure 6-9. Dipole Antenna Patterns



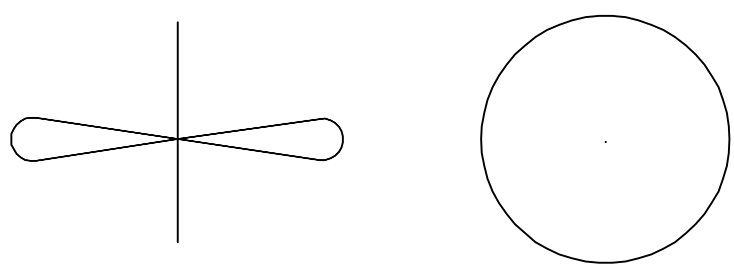
For example, if the *gain* at a base station is doubled, a user will need only half the transmitter power for the same received signal strength at a mobile in the direction of the gain. Similarly, for a given mobile transmitting power, the received signal level will be twice that of a dipole at the base station. And, if there is a potentially interfering signal in a direction other than where the antenna is aimed, that signal strength will be less than it would have been if a dipole were used.

To summarize, by increasing the gain (or directivity) of an antenna in a two-way radio circuit, you may save money by buying a less powerful transmitter, achieve higher received signal levels from stations in the gain direction, and discriminate against signals on the frequency from other directions.

Antenna gains and patterns are identical whether they are used for transmitting or receiving. In other words, to attain gain, the omnidirectional dipole’s donut is flattened.

One way to achieve omnidirectional gain is to stack dipoles end to end with some vertical separation between them. This type of antenna is called a colinear gain antenna. The vertical pattern beamwidth of the donut is squashed, and the energy is more concentrated in the horizontal plane, as shown in figure 6-10.

Figure 6-10. Colinear Array of Two Dipoles - Patterns

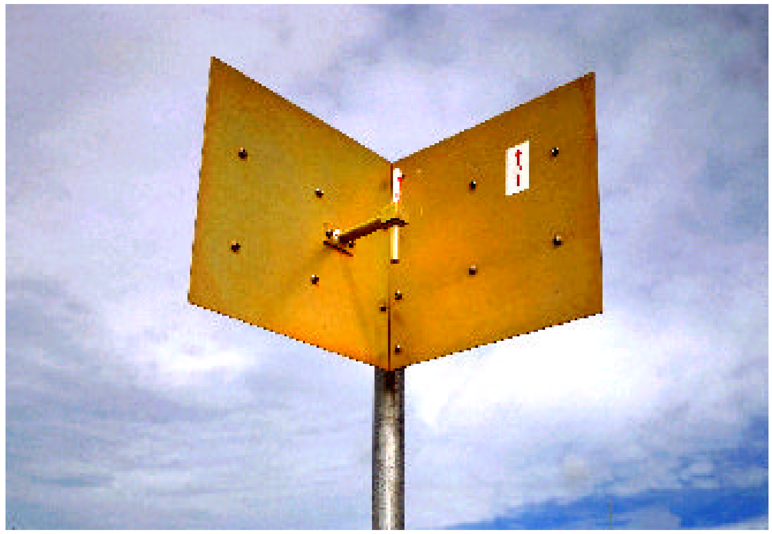


At frequencies of approximately 1 GHz or above, the reference for antenna gain, instead of being a dipole, may be a theoretical element called an *isotropic radiator*. An isotropic radiator is defined as an antenna that radiates equally in all directions (like a sphere instead of a donut). A dipole has a greater gain pattern (1.64 times) than that of an isotropic radiator.

Types of Antennas

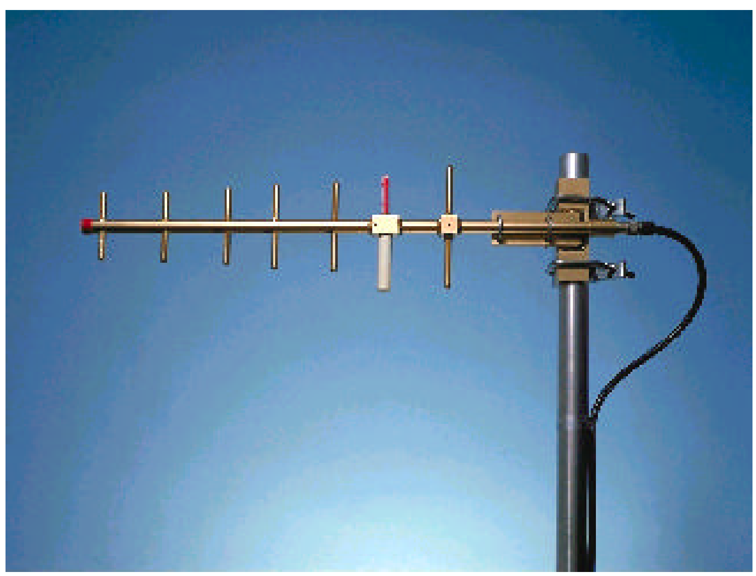
Base station antennas. Most base station antennas are omnidirectional in the horizontal plane (azimuth) so that mobile and portable radios may communicate with a base station from any direction. To increase the transmitter and receiver directivity, many base stations use colinear arrays of dipoles for up to 6-decibel gain at VHF stations and up to 12-decibel gain for UHF stations.

Figure 6-11. Corner Reflector



Directional antennas. Two common directional base station antennas (versus the omnidirectional antennas discussed above) are the corner reflector antenna shown in figure 6-11 and the Yagi antenna shown in figure 6-12. The patterns in both the horizontal and vertical planes are focused and increase the gain considerably over an omnidirectional dipole. (Photographs courtesy of Decibel Products, Dallas, TX.)

Figure 6-12. Yagi Antenna



Because the vertical beamwidth is narrowed as a base station's antenna gain is increased, it is necessary to make sure that the main beam will hit the receiving station antenna. If there are large differences in elevation between transmitting and receiving antennas, there is a possibility of missing them. Base or repeater stations that are placed on very tall buildings or on mountaintops often are designed with a “downtilt” on their patterns to make sure that the maximum radiation hits close-in mobile units.

Mobile antennas. The simplest mobile antenna is a quarter-wave whip antenna. It consists of a single vertical element, approximately 1/4 wavelength long, mounted onto the metal roof of an automobile, and is called a monopole.

The roof acts as a “ground plane” reflector so that the antenna radiation pattern emulates a dipole antenna.

At VHF low band (50 MHz), a quarter wave monopole antenna is about 5 feet long. As the frequency is increased, the length of a monopole antenna is reduced. At 850 MHz, a monopole is only 3.5 inches long.

Portable antennas. Portable radios usually use helically wound or rod antennas attached to the radio. These are usually less efficient than base or mobile antennas. There are also times when your body is between the portable and the base with which it is communicating, causing a decrease in signal. These characteristics must be accounted for in designing a system.

Smart antennas. A new type of antenna used for receivers at cellular and personal communications systems (PCS) sites is called a “smart antenna.” Smart receiving antennas have the ability to focus on a received signal so that it obtains both maximum gain and interference suppression from other signals on the same channel. In other words, the gain of a smart antenna is varied using computer technology toward a particular station to attain the highest received signal level and to discriminate against interfering signals. Smart antennas are generally expensive.

Interference

With the advent of cellular, PCS, specialized mobile radio (SMR) and enhanced specialized mobile radio (ESMR) systems, many new antenna installations must be made throughout the country. To minimize the number of new antenna sites (and associated towers), installations with a multitude of radios combined on a few antennas are becoming more prevalent.

As the number of radios and antennas is increased at a site, the *interference* potential of generating and/or receiving spurious signals is increased. Therefore, filters and isolators (discussed in the next section) must be added to the antenna circuits. Usually, the last station to build at the site causes the interference and is responsible for the additional filtering equipment. Some sites have full-time managers who screen an applicant’s plans to anticipate any interference potential.

Interference may be predicted using a software program by inputting the transmitted signal frequencies and bandwidths and the receiver frequencies and bandwidths. This allows you to determine the intermodulation product frequencies and harmonics that might be generated externally or internally in the equipment. Knowing what may be expected allows you to take preventive action. Some types of filters used are discussed in the duplexers, combiners, and multicouplers sections of this book.

Radiation

Additionally, with high-power transmitter stations there is the potential problem of harmful radiation. Service personnel climbing towers in the vicinity of radiating antennas could be exposed to large amounts of radiation, which can cause excessive skin and body tissue heating or burns. It may be necessary to reduce power or turn off transmitters when these technicians are climbing.

The radiation danger is highest when there are high-power broadcast stations at common sites. Also radiation exposure requirements for the public are less than for personnel associated with the site (see table 9-1 in chapter 9). To help prevent public exposure, security fences usually are constructed around towers, and the fences are posted with "Hazardous RF" signs.

Local Regulations Controlling Antennas

Most cities have zoning ordinances that control the use of land for radio sites. These usually include maximum tower heights and setbacks, as well as the antenna types and radiation characteristics. Usually an application for a radio site is prepared by an applicant and submitted to the zoning board for processing and a recommendation. County commissioners or city council members have the final approval. Members of the public often have the opportunity to voice their opinions regarding the aesthetics and requested use of the site before approval. It is not unusual for a government entity to add stipulations for disguising a tower and antenna. Recent examples include requiring a tower to look like a tree and using a church steeple to house an antenna.

Radio Coverage

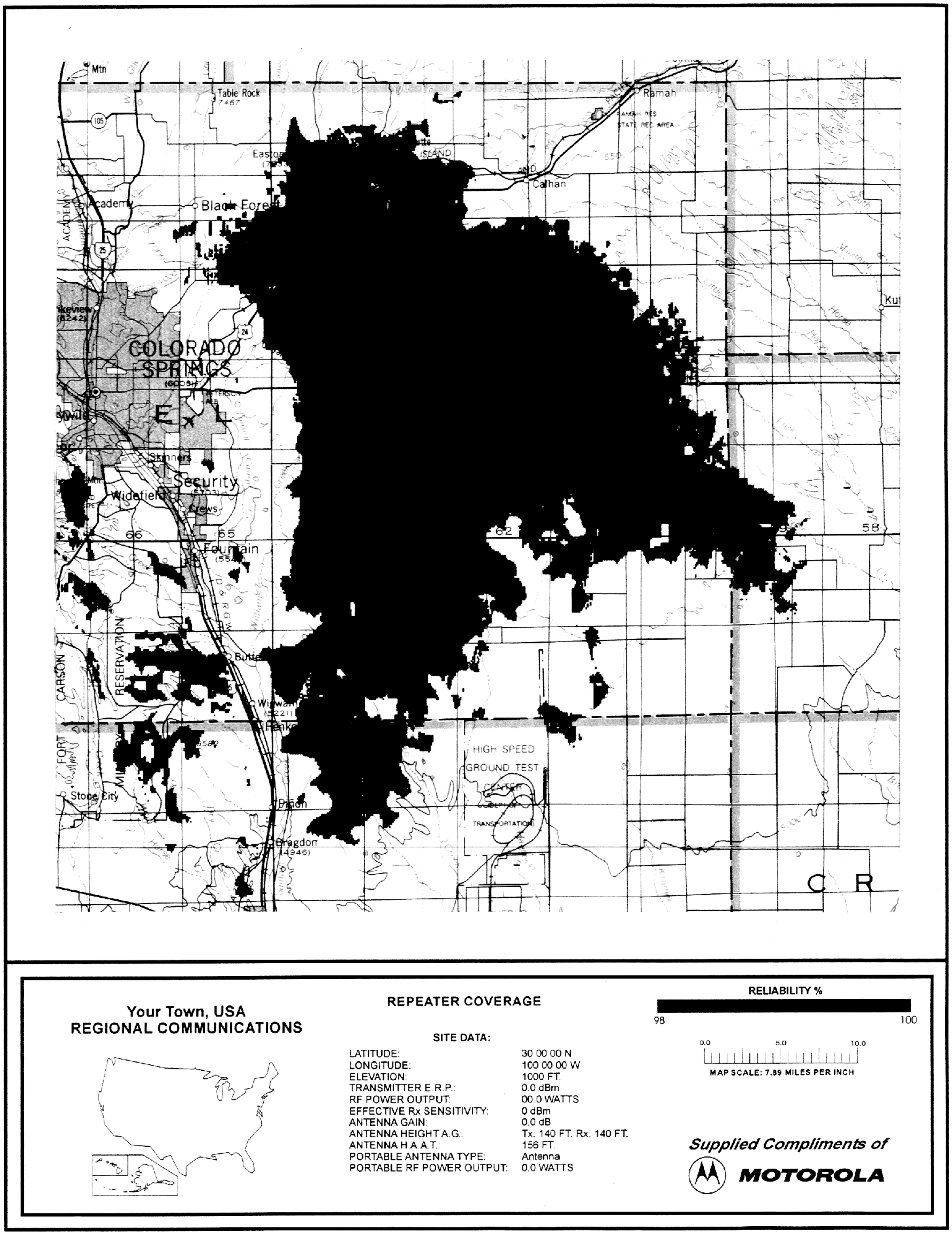
One of the most important characteristics of a radio system is its *coverage*. That is, it is important to know exactly where the base or repeater station signals may be received by mobile or handheld radios and exactly where mobile or handheld radio stations may be heard by a base or repeater station.

All parameters must be placed into one of several computer models (called propagation models) to get a reasonably accurate output. These include transmitter power out, transmission line losses, antenna gain and directivity, foliage losses, building losses (if required), receiver sensitivity, and antenna and transmission line characteristics.

Figure 6-13 shows a typical coverage pattern for a base station (the large black area). Notice that there are some holes in the main contour (white areas within the black area) where signals are not heard, and there are some places (hills) outside of the main contour where there is reception.

These coverage maps, or contour diagrams, are usually made using one of a number of theoretical propagation programs and then running field tests to correct the uncertainty in the models.

Figure 6-13. Sample Coverage Map



Mobile and handheld radios have different characteristics than base stations due to their lower power and to poorer antenna efficiency. Coverage patterns should be made for each kind of radio used in a system so that you know exactly where to expect coverage. If you don't know that an officer's portable radio transmission will not be heard at a repeater, it could put the officer's life in jeopardy.

Coverage should *always* be verified by running actual tests after a system is constructed. There are testing procedures available from some of the larger system suppliers. These include the use of vehicular calibrated receiver systems, which measure the station signal strengths, versus location at points along a predetermined route. Standards are being developed by a Telecommunications Industry Association (TIA) committee consisting of industry and user representatives.

Duplexers, Combiners, Multicouplers

Duplexers, combiners, and multicouplers are components that make it possible to connect multiple transmitters and receivers to antennas. These important filtering and isolating components are used in a radio system to optimize its operation and minimize interference with its own system as well as other systems.

A single *repeater*, consisting of a transmitter and a receiver operating on different frequencies, is most often connected to a common antenna. If the transmitter energy gets into the receiver, it can burn out the front-end components or cause severe interference in the receiver and, as a result, in your overall system.

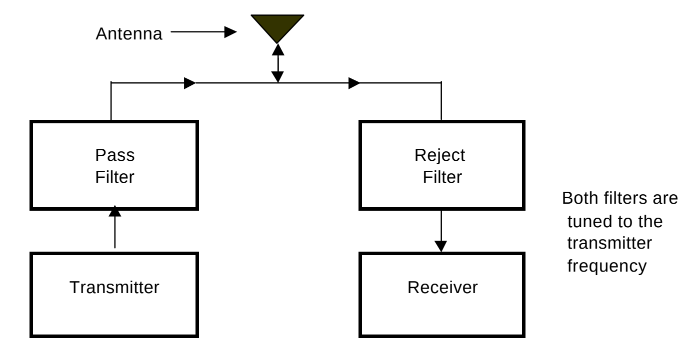
You can use two antennas, one above the other, but this configuration may still not provide enough isolation. Therefore, a duplexer may be used to increase the isolation and to keep the transmission from interfering with received signals.

Duplexers

To shield the receiver from the transmitter, *cavity filters* are often added in the transmitter and receiver transmission lines to form a circuit called a *duplexer*. There are several configurations.

One method of duplexing is by placing a "pass" filter in the transmitting line and a "reject" filter in the receiving line with both filters tuned to the transmitter frequency, as shown in figure 6-14. When the appropriate isolating components are selected, the receiver does not experience interference from the transmitter.

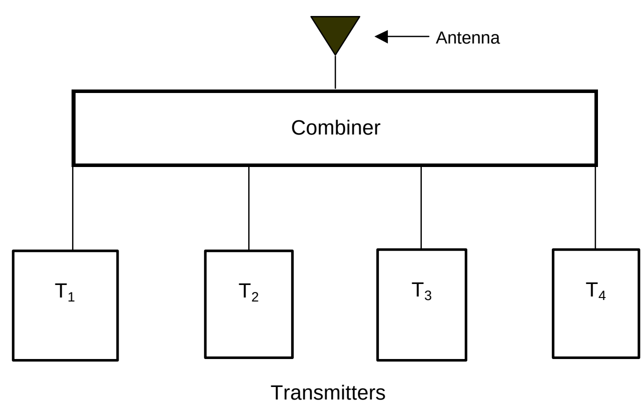
Figure 6-14. Duplexer



Combiners

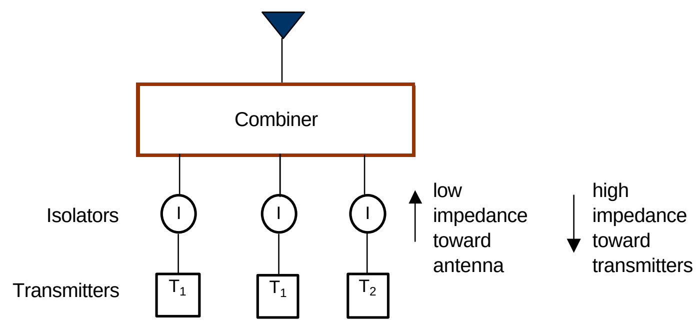
When trunked radio systems are used with a multitude of transmitters connected to an antenna, a circuit element called a *combiner* is used to combine the output signals. The combiner allows the transmitter outputs to be coupled together to send the full output power of each to the antenna, as shown in figure 6-15.

Figure 6-15. Transmitter Combiner



An additional element may be used in the circuit between each transmitter and the combiner to increase isolation to the other transmitter outputs. Such an element is called an *isolator*, as shown in figure 6-16.

Figure 6-16. Isolators

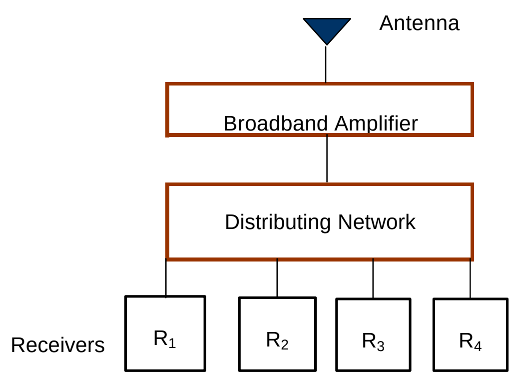


If there is inadequate isolation, the mixing of the transmitted signals can cause the generation of additional frequencies called intermodulation products, or IM products, which cause interference to nearby receivers.

Multicouplers

A device similar to a combiner, called a *multicoupler*, is used to connect a multitude of receivers to a single antenna. Usually, a multicoupler contains an amplifier that covers all the receiving frequencies and then splits and sends each signal to its particular receiver, as shown in figure 6-17.

Figure 6-17. Receiver Multicoupler



Multiple Access Systems

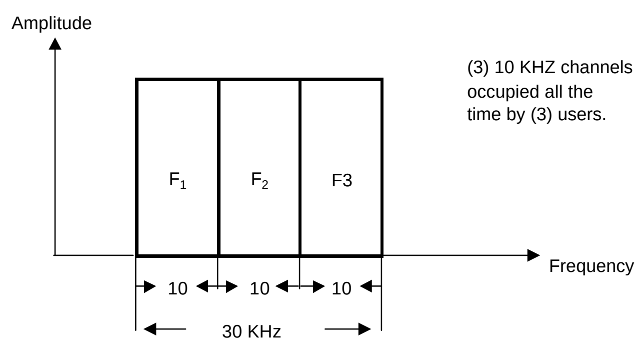
Several cellular radio systems are used to improve spectrum efficiency, systems that allow more users to employ a channel or frequency band. They are frequency division multiple access (FDMA), time division multiple access (TDMA), and code division multiple access (CDMA). Examples are discussed below.

Frequency Division Multiple Access (FDMA)

The original cellular radio channels were 30 KHz wide and accommodated one voice signal subscriber. As the number of subscribers increased, some cellular radio companies opted to divide the 30 KHz channels into three 10 KHz channels, which would allow a 3:1 increase in subscribers, as shown in figure 6-18. The process is called frequency division.

Multiple access is accomplished by the cellular radio system control computer having the ability to assign each of the channels to different subscribers. When one subscriber has completed a call or moves into a new cell, the channel may be reassigned to another subscriber.

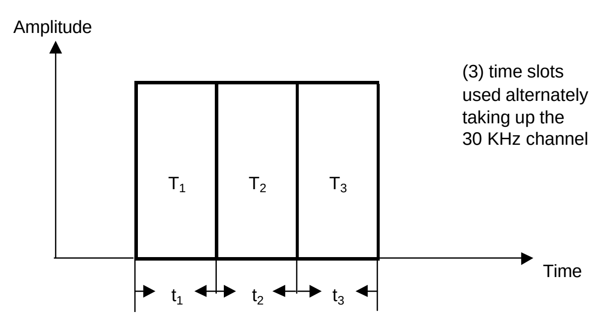
Figure 6-18. Frequency Division Muliple Access (FDMA)



Time Division Multiple Access (TDMA)

Another scheme used by cellular companies is to take the same 30 KHz channel, but instead of dividing it into three narrower channels, it is set up for transmission in three time periods so that three subscribers still use the total 30 KHz; now each subscriber would talk for one-third of the time, thus increasing the number of users by 3:1. By allowing each subscriber to talk for a few milliseconds in rotation, three conversations now take place within the same 30 KHz channel. See figure 6-19.

Figure 6-19. Time Division Multiple Access (TDMA)



For time division transmission to work, the voice signal must be digitized by a vocoder (voice coder) and each digitized signal is sent in sequence over the 30 KHz spectrum. The subscriber's phone must be perfectly synchronized with the transmission so that it only decodes the desired subscriber's signal in its vocoder. Cell phone and PCS companies have found that by using TDMA, up to eight subscribers may use the same 30 KHz spectrum. Multiple access is accomplished in the same manner as in FDMA above.

Group of special mobile (GSM), which was developed in Europe and is being used by a number of U.S. companies, provides TDMA transmission with 200 KHz wide channels in the 2 GHz band.

Code Division Multiple Access (CDMA)

CDMA uses spread spectrum techniques and is more complex than either FDMA or TDMA. The transmission spectrum is always much wider than that required to transmit information. Two types of systems are used: *frequency hopping* and *direct sequence.* Both systems use vocoders to digitize the signal.

Frequency hopping. The frequency hopping concept is easy to visualize. The transmitter changes frequency every few milliseconds in a prescribed manner as it transmits information. A perfectly synchronized receiver follows the frequency change sequences of the transmitter from one frequency to another to receive the information.

By having as many different frequency changing sequences as there are radios in a given area, many conversations may occur at the same time over the same spectrum. When two transmitter signals collide on the same frequency, the receiving phone transmits a message that it was not received and the original information is resent.

☞ Did you know?

The original patent for CDMA was assigned to Hedy Lamarr, the movie star, who developed the concept during World War II.

Direct sequence. In the direct sequence CDMA, the transmitted digital signals are coded by a "spreading circuit" in each transmitter. Each receiver has a decoder that deciphers the spread signal and recovers the voice. There are different coded spreading circuits for each set of users.

Packaging Data

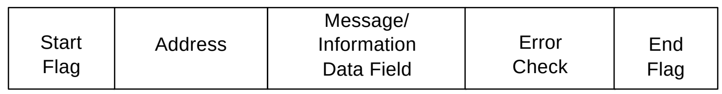
Packet radio is a heavily used technology for transmitting and receiving data, such as National Crime Information Center (NCIC) data, from a patrol car to NCIC. Packet radio is a computer-to-computer communications mode in which information is broken into short bursts containing a message. The bursts (packets) also contain addressing and error detection information.[1]

One method for packaging data is called Cellular Digital Packet Data (CDPD). Additional discussion of this particular method is given in chapter 7.

[1] *1995 ARRL Handbook,* 72nd Edition, P. 1.10, Newington, CT: American Radio Relay League.

A typical packet frame protocol as composed on a computer is shown in figure 6-20. The packet begins with a flag that signals the beginning of a frame. Next is the address of the packet, then the message or information data field, next an error-checking portion, and finally an end-of-frame flag. Usually about 1,000 bytes are transmitted in a packet. When the packet arrives at the address receiving computer, the packet information is stripped off and checked for errors.

Figure 6-20. Typical Packet Frame



If a message is so large that several packets must be sent, the field contains information for the computer to reassemble the original message in the proper order. If a packet is lost, the receiving computer acknowledges it to the originating computer, and the packet is resent.

There are several world standards for packet communications. One well-used standard for data packet transmission is CCITT X.25. Specialized software is required to run packet radio systems.

Chapter 7

Current Public Safety Radio Systems

Paging Systems

Paging systems are single-frequency, one-way radio systems used for making people aware that they are being sought. The original local government pagers were voice pagers used for calling out volunteer fire departments (many of which are still in use). Modern pagers have alphanumeric readouts and are capable of storing a number of messages. Pagers are used by volunteer fire departments, police officers, emergency medical personnel, service personnel and technicians, and even children whose parents wish to keep track of them.

Very reliable commercial paging services are available in most regions of the United States at reasonable subscription rates. Many are used by local police, fire, and emergency medical services (EMS) units.

Alerts are given by a tone or a set of tones or by a built-in vibrator for use where tones are not permissible. There are many local and national suppliers of paging services and pagers.

Paging is accomplished at many different frequency bands including VHF, UHF, and FM broadcast. Two standards are especially popular at this time, but many others exist. These include the British Post Office standard, called POCSAG (Post Office Code Standardization Advisory Group), and Motorola's FLEX™ system.

Statewide and nationwide paging is accomplished by transmitting the paging information over telephone lines or via satellites to paging transmitters for retransmission. When it is necessary to page over a wide area, a multitude of paging transmitters are activated at the same time in a simulcasting fashion.

The FCC has auctioned off a number of pairs of frequencies for two-way paging in the 800 MHz band (PCS narrowband). Each uses a 50 KHz bandwidth in one direction to accommodate high-speed data transmission, which is paired with either 50 KHz or 12.5 KHz in the reverse direction for returning data. The FCC also authorized some paging response frequencies for paging users who are already licensed under parts 22 and 90 of the FCC Rules, under certain circumstances.

Two-Way Simplex Radio Systems

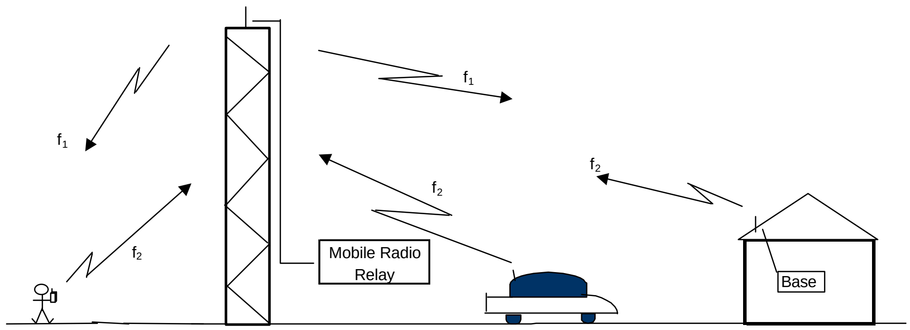
Two-way radio systems using one frequency are called simplex radio systems. Base stations, mobiles, and handheld radios communicate on a single frequency. Most radio channels today are 25 or 30 KHz wide, depending on the frequency band, and use FM as required by part 90 of the FCC Rules. The FCC has begun to implement new technology to narrow the radio bandwidth to accommodate additional radio stations. Base stations usually have high antenna installations to make sure that they can attain the desired radio coverage area. One problem with a simplex system is that handheld and mobile radios cannot communicate very far with each other because of their low antenna heights and are usually limited to just a few miles in flat terrain. Therefore, the person at the base station must repeat transmissions from one mobile to another. To alleviate this situation, the mobile relay or community repeater was developed.

Two-Way Mobile Relay Systems

Two-way mobile relay systems are also called mobile repeaters, community repeaters, or just plain repeaters. In this discussion, all these terms are used interchangeably.

The community repeater makes use of two frequencies. The repeater radio functions as an amplified relay station receiving high- or low-power base stations, low-level mobile, and handheld radio signals, changing their frequency, amplifying the signals, and retransmitting them on the repeater output frequency. Figure 7-1 shows the use of frequencies in a repeater configuration. In the figure, f_1 is the output frequency of the repeater and the input frequency to all base, mobile, and handheld radios and f_2 is the output frequency of the base, mobile, and handheld radios and the input frequency of the repeater. Repeaters are generally installed on the highest points within the coverage areas, including high buildings and mountaintops where the topography allows for maximum coverage and penetration. Thus, regardless of the output or the antenna heights on handheld, mobile, and base radios, the repeater signal is always the same strength at any receiving site.

Figure 7-1. Community Repeater System



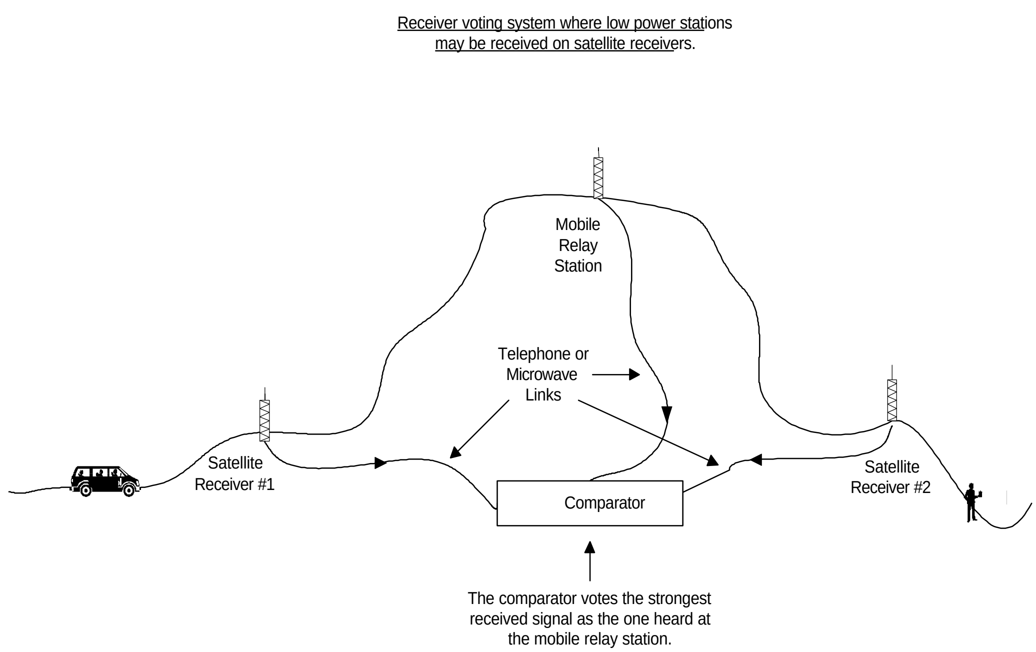
Mobiles, low power base and handheld radios transmit on frequency f_2. The signals are detected by the repeater and remodulate a transmitter on f_1 at the mobile relay site.

Twice the bandwidth of a simplex system is now required, further aggravating the spectrum efficiency problem. Voice FM simplex and repeater radio systems suffer from other disadvantages too. For example, when a base or repeater is placed on a high point, it usually covers distances up to 60 miles in radius and, although not usually needed by the licensee, negates the option of relicensing the frequency to another user up to 120 miles from the licensee.

Repeater Innovations

Repeater stations are usually high-power stations, 600 to 3,500 watts ERP, and cover a large area. Handheld radios, with their low output power of 0.5 to 3 watts ERP, are often unable to be heard at the repeater site, particularly in hilly or mountainous terrain or in urban areas having numerous tall buildings. To correct this power imbalance, one or more satellite receiving sites may be set up in these coverage areas close to the low-power radios to receive the low-power signals. Each satellite receiver's output is sent via telephone line or microwave radio transmission to a signal comparator at a central site, where the strongest signal is selected through "voting" and utilized to drive the repeater. The scheme is shown in figure 7-2.

Figure 7-2. Receiver Voting System



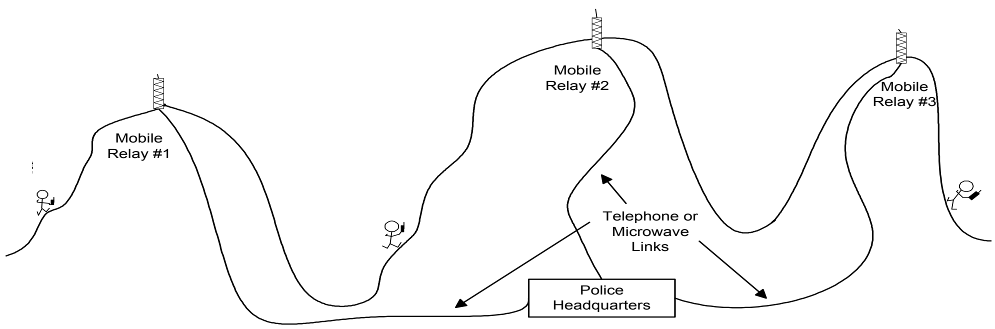
Another scheme used where there are problems transmitting to and receiving from mobiles and handheld radios due to large changes in topography requires several repeaters at different locations that may be switched at a central position, usually at the police communications dispatch center, to the repeater receiving the highest signal level. In this way the signal is "steered" toward the station, as shown in figure 7-3.

Where very large areas are to be covered, for example several counties, simulcast systems using multiple repeaters operating on the same frequency may be employed. Special emphasis must be placed on frequency stability of the carriers, for they must be within a few Hertz at all stations; the modulation must be transmitted at exactly the same time, or there will be interference in the overlap zones of the repeaters. Frequency and time stability can be accomplished by the use of microwave communications systems or by using the clock signals received from a global satellite system (such as GPS).

Mobile Repeaters

Small vehicular repeaters have been used to relay transmissions from handheld radios through the main vehicle radio to headquarters when an officer is in an area where he or she cannot reach the base repeater. An example of this is when an investigator, located in the concrete basement of a shopping center, can use a small 450 MHz repeater in the investigator's vehicle to bridge communications between the basement and headquarters.

Figure 7-3. Repeater Steering



At Police Headquarters, the repeater that receives the strongest signal is the one used to transmit to that user.

These repeaters have been used traditionally in the 150 and 450 MHz bands, and the concept is being explored for 800 MHz use by agencies and frequency coordinators.

Trunked Radio Systems

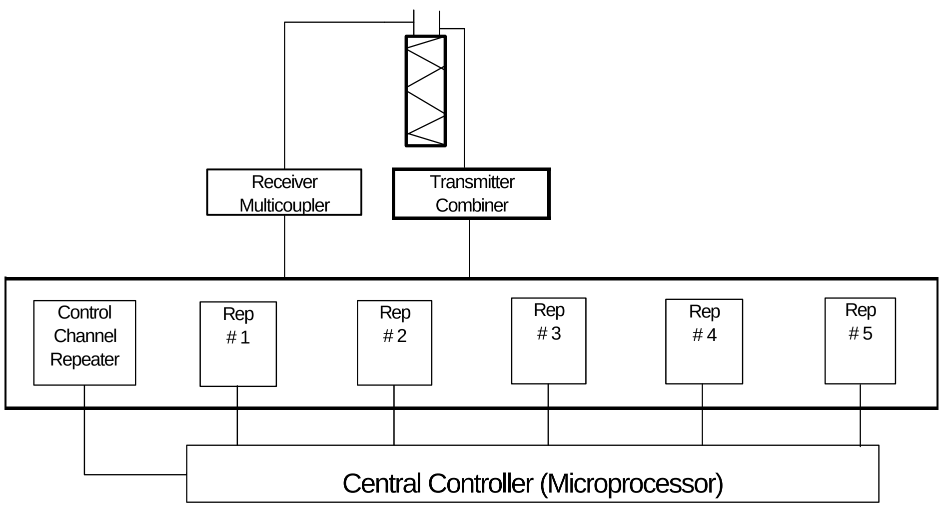
Public safety organizations have traditionally used dedicated community repeaters. For example, in many communities, separate repeaters are used by the police department, the fire department, administrative departments, and road maintenance department, although the transmission loading is unequal for the departments most of the time.

If a police department needs to use two repeaters for operation and the road maintenance's repeater is available, the department may be unable to use it. To use it requires that the department's mobiles tune their receivers to road maintenance's frequency and that the police dispatch has an extra base station to contact the road maintenance repeater. This scenario is not very practical.

A community repeater cannot be borrowed by another user, so it often sits vacant on a usable frequency while a user needing to transmit more information on his or her radio system must wait until the repeater is free. To solve this problem and to improve the spectrum efficiency, the industry developed a "trunked" system concept borrowed from the telephone company industry.

With reference to figure 7-4, one can think of this as a box containing a number of repeaters, each of which may be switched into a radio circuit as needed. For example, if there are five trunked repeaters and repeaters #1 and #2 are in use, a central controller will designate #3 as the next repeater to be used when the need arises. If #1, #3, #4, and #5 are in use, it will designate #2 for the next user. In this way, repeaters do not stand vacant and the spectrum is more fully used.

Figure 7-4. Simplified Five Channel Trunked Radio System



Control channel is a dedicated data channel. Mobile units monitor the control channel. If a mobile wishes to contact a base or other mobile station, it initiates a call with its ID and the ID of the unit to be called over the control channel. The called station constantly monitors the control channel. The central controller selects an unused repeater and sends data to both units to set up the repeater's transmitting and receiving frequencies on their units. A conversation can then take place. When done the units again monitor the control repeater.

The FCC amended its Rules so that any licensee requiring five or more channels *must* use a trunked radio scheme.[2] Systems in place before the regulation was issued are "grandfathered in" and may add single repeater stations as necessary.

Two technological breakthroughs have made trunked radio systems possible: 1) the development of microprocessors and personal computers, with their associated software and 2) synthesized frequency generators. Microprocessors allow the logical selection of frequencies for the repeaters. Frequency synthesizers at the repeater and mobile and portable stations allow the radios to set up individual transmitting and receiving frequencies as designated by the base station microprocessor called the "central controller."

One scheme used to inform the central controller that there is a need for a repeater is a dedicated data control channel (repeater), which monitors mobiles and handheld stations at the base station. If a user desires to speak with another user or a group of users, he or she initiates a transmission on the data control

[2] FCC Docket 18262.

channel indicating his or her ID number and requesting that he or she talk with another user or a group of users by indicating the group's or individual's ID number. The control channel repeater acknowledges the transmission, and the central controller determines the available repeater and commands the initiator and the target station(s) to change their operating frequencies to that of the assigned repeater. A voice conversation may then take place. After the conversation, the radios return to monitoring the control channel and the central controller determines that the repeater is now available for other use. Note that these systems are totally software driven.

Besides dedicating a single repeater for control, there are other schemes that can be used. For example, the control channel may be rotated from one channel to another. Each time it is moved, the subscriber's units must change frequency and track it.

Trunked radio systems are generally used in the 800/900 MHz bands. The latest FCC Rules now allow for VHF trunking systems to be developed, provided that they do not interfere with existing radio systems in surrounding areas.

Major suppliers of trunked radio systems are Motorola, ComNet Ericsson Critical Radio Systems, and the E.F. Johnson® Division of Transcrypt.

Specialized Mobile Radio (SMR)

Besides local government and law enforcement, trunked radio systems are used by large electric, gas, oil, and other industries to improve their efficiencies. A specific class of service, called "specialized mobile radio" was designated by the FCC to allow the set up of trunked systems that could be used to sell radio services to commercial and government users. The authors discuss these offerings later in this book as a reliable option, where available, for law enforcement.

The channel bandwidth set up for trunked activities is 30 KHz wide in the 800/900 MHz band. Original applicants used analog radios; however, enhanced specialized mobile radio has been the name given for digital SMR systems. Nextel is one supplier providing ESMR services nationally. Commercial services of trunked SMRs and ESMRs also are examined later in this guidebook.

APCO Project 16 Trunked Radio System

The Law Enforcement Assistance Administration (LEAA) in 1977 provided a grant to the Association of Public-Safety Communications Officials-International (APCO) to make possible the opportunity for the public safety community to develop test beds and study various parameters associated with UHF band trunking systems.

APCO Project 16 members were charged with evaluating the technical, economic, and regulatory questions raised by the 800/900 MHz spectrum made available by the FCC. Studies were made on three experimental systems in Chicago, Miami, and Orange County, California.

When the study was completed, APCO published a document defining the mandatory and desirable functional capabilities for a public safety analog trunked radio system. It was issued in March 1979 and was called *900 MHz Trunked Communications System Functional Requirements Development.* The requirements were tailored for law enforcement and addressed channel access times, automated priority recognition, data systems interface, individuality of system users, command/control flexibility, systems growth capability, frequency utilization, and reliability.[3]

APCO 16 systems are presently being used by most large and medium-sized government agencies. To make the technology available to smaller government groups in adjoining cities, some communities are sharing systems. This has cut down on both capital investment and operating costs by any single entity.

The APCO 16 specification had no interoperability or encryption requirements; thus systems supplied by different manufacturers do not talk to one another. This limits competitive bidding for expansion and replacement parts.

A new digital system specification, under the APCO Project 25 Committee, has been in process for years to correct some of the interoperability difficulties, improve spectrum efficiency, and take into account the changing world to more efficiently and economically manufacture digital radio systems.

APCO Project 25 Digital Trunked Radio System

APCO formed a working group called APCO Project 25 (now called simply Project 25) for the development of a digitally trunked radio system specification tailored to public safety needs. Associations and agencies including the National Association of State Telecommunications Directors (NASTD), National Telecommunications and Information Agency (NTIA), National Communications System (NCS), Department of Defense (DoD), APCO Canada, and British Home Office were brought into the process to obtain as many contributions as possible to make the resulting specification a world standard for digital land public safety mobile radio. The Telecommunications Industry Association has been involved with the Project 25 group by providing technical support and the mechanics of standards writing, which has made the resulting specification (ANSI/TIA 102) into the national industry standard.

The objectives of Project 25 are: to maximize spectrum efficiency; to ensure competition in life cycle procurements; to allow effective and efficient inter- and intra-agency communications; and to provide "user-friendly" equipment and operation. Services defined include digital voice address including individual, group, and broadcast calls; circuit data including protected and unprotected data, packet data, and a set of nine supplementary services including encryption. Both conventional and trunked air interface specifications are included. The specification will be used for unit-to-unit direct communications, base station to limited field units, multisite simulcast, voting receiver systems, and wide and local area trunking at frequencies from 100 to 1000 MHz.

[3] APCO, *900 MHz Trunked Communications System Functional Requirements Development,* Executive Summary, March 1979.

As stated above, the APCO Project 16 standard resulted in a number of competing analog systems that were unable to communicate with one another, and high on Project 25's list of requirements is a common air interface between systems of different manufacturers enabling interoperability. In addition, there are common interfaces spelled out for the data port for laptop and other terminals, the host computer and other networks, the public telephone system interconnect, the network manager, and for connecting multiple systems (inter-system). Thus, competing companies may design their own offerings provided the common interface requirements are met.

After a number of different systems were investigated, the committee chose an FDMA access scheme proposed by Motorola, Inc. The scheme initially involves 12.5 KHz channel bandwidth, later to migrate to 6.25 KHz bandwidth.

A migration strategy has been defined in Project 25 that allows forward migration to 6.25 KHz bandwidth and backward migration to 25 KHz trunked radio systems including the APCO 16 systems. The system is heavily software driven, and Motorola has licensed its scheme and software to other vendors without royalties so that other vendors may produce APCO 25 compliant systems in competition with them.

The 12.5 KHz air interface has been published, although the dataport, data host, and network management interfaces are still being worked on.

Several large-scale Project 25 systems are now in use, including State government systems for Florida and New Hampshire.

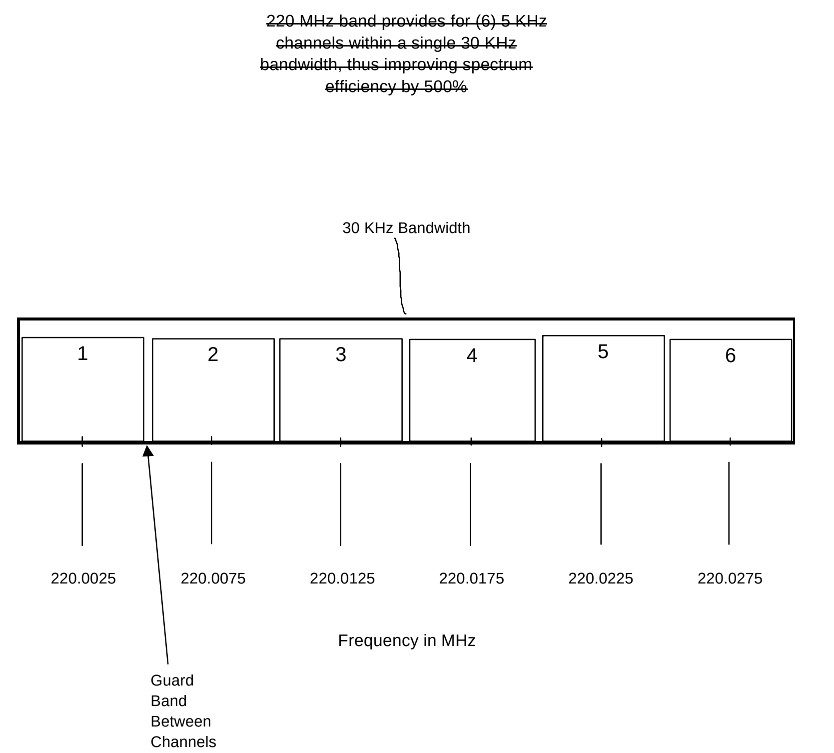
220 MHz Narrow Bandwidth Band

The FCC recently reallocated the frequencies from 220 to 222 MHz for narrow bandwidth communications use. The channel bandwidth in this frequency band is only 5 KHz so as many as 6 channels may be substituted for a single 30 KHz FM channel (i.e., 6 signals where there was one, with a subsequent increase in spectrum efficiency of 5:1). See figure 7-5. The FCC has auctioned off frequencies in this band for regional and nationwide licensing.

TErrestrial TRunked RAdio (TETRA)

While the Project 25 committee elected to standardize on a FDMA scheme for the 12.5 KHz first phase of Project 25, a European standards committee selected a TDMA trunking technology it called TErrestrial TRunked RAdio (TETRA). TETRA uses 25 KHz of bandwidth that allow packet-switched data at rates up to 28 kbps. The standard can provide up to four voice or data channels within a 25 KHz bandwidth, thus providing the equivalent efficiency of a single channel of 6.25 KHz (which is required in Phase 2 of Project 25). The Project 25 steering committee is considering the integration of TETRA technology within Phase 2. Over-the-air interoperability and other standard interface requirements of Phase 2 still need to be met. The first TETRA law enforcement communications system was employed in Finland using Nokia equipment. Motorola has supplied a system to public safety organizations for the Island of Jersey (United Kingdom), New Zealand, Poland, and Hong Kong. These systems use trunked radio configurations driven by software, so that many different schemes may be dynamically employed to adjust to different situations.

Figure 7-5. 220 MHz Frequency Plan Versus 30 KHz Channel



One method to accomplish getting a voice channel within 5 KHz is to use a type of modulation called "amplitude compandered single sideband" (ACSB). Other narrowband techniques were developed along with ACSB, some resulting in the ability to transmit voice and data at rates up to 16.8 Kbps.[4]

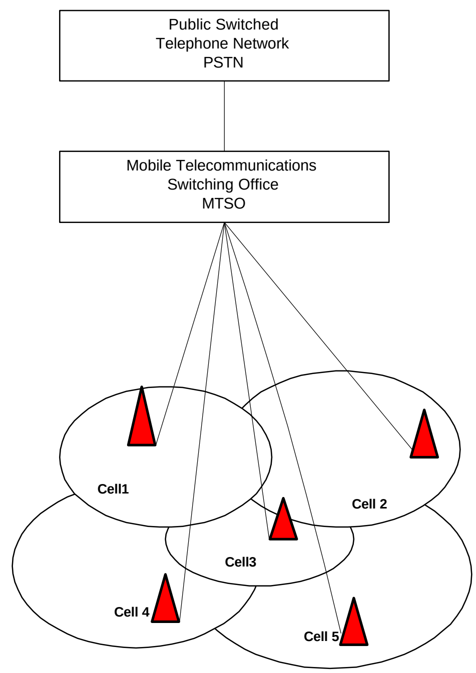
Cellular Radio/Telephone Systems

Cellular mobile radio was developed by AT&T. Originally, two licenses were awarded in each coverage area: one to a wire company and the other to a wireless company in almost all metropolitan and rural areas. The cellular scheme allows for a large number of users over a given coverage area to connect to the Public Switched Telephone Network (PSTN). A great deal of the United States is now covered by cellular radio, and many law enforcement departments use cellular to supplement their radio communications systems.

[4] *Linear Modulation Brochure,* Midland USA, Inc., 1998.

The cellular system employs a number of coverage cells within a geographical area, as shown in figure 7-6. Each cell uses a trunked radio system to supply repeaters to users within the cell. Cells are connected to a Mobile Telephone Switching Office (MTSO) by trunked phone lines, fiberoptic cables, or microwave links. Cells can range from 30 miles down to 0.5 miles in diameter. When a cell reaches the maximum capacity of subscribers, it may be divided in two by adding new antennas and trunked radios and reducing power output to double the original capacity.

Figure 7-6. Cellular Radio System



When a subscriber turns on a cell phone, an indicator shows whether there is sufficient signal to connect to a cell. When a number is called, a dedicated radio control channel receives the information and sends it through the MTSO to the PSTN system to ring the called person's number. When the call is answered, the MTSO sets up a dedicated cell repeater for the subscriber to use for the conversation.

At the time of the conversation, the cell phone signal strength is monitored at the cell where the conversation is taking place, as well as at adjacent cells. If the signal strength gets stronger in another cell, the MTSO requests that a new repeater in that cell take over the conversation. The "hand-off" is accomplished seamlessly within 1/5 of a second. When the conversation is completed and the subscriber hangs up, the MTSO returns the repeater channel for use in another phone call.

If a call is made from the PSTN to a cellular subscriber, a set of dedicated paging channels at all the cell sites calls the subscriber's number. When the subscriber's cell phone hears the page, the called subscriber answers the cell phone and the phone signals back through the control channel that the call has been answered. This triggers the MTSO to set up a repeater for the conversation. When the subscriber hangs up, the MTSO releases the channel for another call, as described above.

The original cellular system, called Advanced Mobile Phone System (AMPS), uses frequency modulated repeaters with 30 KHz of bandwidth in each direction for one conversation. To improve the spectrum efficiency, a frequency division multiplexing system allowing three 10 KHz channels in the 30 KHz bandwidth was developed called Narrowband Advanced Mobile Phone System (NAMPS). As the service developed over the years, several even more efficient technologies were developed using time division multiple access (TDMA) and code division multiple access (CDMA), which are discussed elsewhere in this book.

Strengths of the cellular system are:

1. A very large number of subscribers can be accommodated.

2. As the subscriber numbers in a cell reach the cell capacity, the cell may be divided to double its capacity.

3. By keeping the transmitter power low in each cell, transmitting frequencies may be repeated in nearby cells, thus increasing spectrum efficiency.

4. Cellular radio systems tend to be highly reliable even under the worst environmental conditions.

One weakness is that, with several different modulation schemes now being used, every cell phone does not work in every system. Multimode phones have been developed to solve this problem.

Personal Communications Systems (PCS)

Because of the need for more frequencies for personal communications and the popularity and demand for cellular radio, the FCC reallocated several megahertz of frequencies in the 900 MHz range and a large portion of the 2 GHz band for PCS. These frequencies were auctioned off to the highest bidder by the FCC.

The 900 MHz spectrum is allocated into 50 KHz channels, some paired with other 50 KHz channels and some with 12.5 KHz channels.[5] These are being used for two-way paging, data transmission systems for carrying stock market and other information, and other uses conceived by the auction winners.

The 2 GHz band was auctioned off in much larger bandwidth segments, up to 30 MHz. (A small portion of the band was allocated for unlicensed operation to operate wireless PBX's and other in-building voice and data communications networks.) The broadband spectrum contains very few technical limitations for service offerings so that companies with unique communications schemes might make creative use of the spectrum. However, so far, most offerings made public appear to be for additional cellular radio systems.

Buildouts are proceeding initially in high-density population areas where licensees can get a quick payback, so many rural areas may have to wait for service. Because of the number of winners in various areas, there may be as many as six competitors in the densely populated areas.

Some seven different de facto technical approaches to these new cellular radio systems exist, so a telephone used in one system will not necessarily work with another. Some confusion also exists between the 800 MHz cellular services and the 2 GHz PCS cellular services because of advertising claims. Today, technologies used for cellular and PCS are basically the same and the offerings are very similar. However, PCS has the potential to provide other services in addition to cellular. People must wait and see as the technologies mature.

[5] FCC *Rules and Regulations*, Section 24.129, Frequencies.

Cellular Digital Packet Data

Cellular Digital Packet Data, or as it's more commonly called, CDPD, consists of using cellular radio repeaters for the transmission of small bursts of data known as packets. The CDPD process allows the insertion of packets of data in between lightly modulated cellular radio voice channels without reducing cell phone voice capabilities. CDPD is an open transmission methodology for sending data on existing Advanced Mobile Phone Service (AMPS) cellular networks at a transmission rate of 19.2 kilobits per second. The need for sending digital packet data has increased over the years, so dedicated CDPD channels have been set up by some of the cellular providers.

Law enforcement agencies have found that using laptop computers to obtain critical information in patrol cars without having to go through radio dispatchers improves their officers' efficiency, decreases the information delivery time, and reduces errors. Using CDPD to bypass a dispatcher, field officers may obtain information directly from NCIC to check driver's license validity, existing warrants, and other information that may be of use to an officer in processing a suspect.

The option of using CDPD minimizes the capital outlay by a public safety agency, since it is only necessary to purchase the in-vehicle equipment (e.g., laptop computers with modems and software) rather than purchasing the entire radio communications network for data transmission support.

Public safety agencies wanting to use CDPD should check with cellular service providers in their region to see if they offer CDPD. Then they need to carefully check coverage to make sure that their operating area is adequately covered. Most cellular radio suppliers provide coverage diagrams for subscribers, and many are available instantly over the Internet.

CDPD pricing is traditionally based on the number of bits transmitted, which is difficult to estimate for budgeting. Recognizing the fixed budget nature of public safety departments, one vendor has started offering fixed monthly fee contracts, but so far no other companies have followed that vendor's lead.

The network architecture uses the protocol used in the Internet (i.e., Transmission Control Protocol/ Internet Protocol, or TCP/IP). Therefore, any standard personal computer modem that works with the Internet will operate with a CDPD system; however, special software must be used.

Point-To-Point Microwave Communications Systems

Often you need to connect telephone circuits from one terminal to another, voice and control circuits to repeaters and trunked systems, voting receiver inputs from satellite sites to a comparator, T1 (1.5 Mbps) or T3 (45 Mbps) data circuits, and other communications circuits from one point to another point. Generally, these needs may be fulfilled economically and reliably by leasing wire or fiber-optic circuits from the local telephone or cable company.

When a telephone company expands capacity, it usually overbuilds to allow for future customers. If the circuits exist, leasing payments involve only operational and maintenance costs. However, if the circuits do not exist, you must pay the up-front capital costs involved in constructing the new facilities.

The economies of building a private microwave system usually are in your favor when it is necessary to provide service to an area that would require new facility construction by the telephone company.

The microwave bands include frequencies generally above 960 MHz, or approximately 1 GHz. (Frequency bands used for commercial purposes are in the 960 MHz and 2, 4, 6, 11, 18, and 23 GHz areas.) The 960 MHz band can be used to transmit up to 15 narrowband voice or data channels; the other frequency bands have considerably wider bandwidths to accommodate many more voice and data channels. Microwave systems may be either analog or digital radio systems.

Microwave propagation is considered “line of sight” (LOS), so transmissions must be repeated at approximately 25-mile increments in bands up to12 GHz. In mountain areas, the spacing may be as great as 60 miles. Above 10 GHz, rain attenuation usually causes a distance limitation, so repeaters must be more closely spaced depending upon the amount of rain in different parts of the country.

Licensing

Most microwave systems require FCC licensing under part 101 of the Rules and Regulations. Frequency coordination is required, and FCC Application Form 415 must be filled out. The Commission is experimenting with a Universal Licensing System (ULS) using FCC Form 601, which will be implemented during the year 2000. There is a class of microwave systems not requiring licensing by the Commission under part 15 of the Rules. Most unlicensed systems use spread spectrum modulation, which spreads the power level over a large bandwidth.

PART 3

WIRELESS COMMUNICATIONS ISSUES

This portion of the handbook is a brief description of frequency licensing and pertinent FCC Rules, a description of the newly reallocated television channel frequencies for public safety, a discussion of the FCC's "refarming" policy, a discussion of FCC radiation specifications (OET Bulletin 65), and information on the FBI NCIC 2000 initiative. A brief discussion of future trends, including sharing of spectrum resources between Federal and State/local agencies, also is included.

Chapter 8

FCC Licensing, Rules, Regulations, and Related Issues

The FCC Rules and Regulations are printed in the Code of Federal Regulations (CFR), Title 47. Copies of the rules may be purchased from the Government Printing Office (GPO) (see resources in appendix D). The following parts of CFR 47 are of interest for mobile radio communications services:

Part 90 - Private Land Mobile Radio Services (PLMRS).
Part 22 - Public Mobile Services.
Part 24 - Personal Communications Services (PCS).
Part 101 - Fixed Microwave Services.

Copies of the Rules may be downloaded from the FCC Web site (see resources in appendix D) or purchased at GPO bookstores.

Licensing

If you are buying a system or constructing it yourself, you will need to apply for a license. However, before applying to the FCC, you must obtain specific frequencies of operation from a frequency coordinator. The coordinator will check to see if any frequencies are available in your area and assist you in evaluating your options.

There are four coordinating bodies responsible for public safety-related frequencies:

APCO - Association of Public-Safety Communications Officials.
IMSA - International Municipal Signal Association.
FCCA - Forestry Conservation Communication Association.
AASHTO - American Association of State Highway Transportation Officials.

In the past, the coordinator for most local public safety frequencies has been APCO. However, with the implementation of refarming (see the end of this chapter), applicants may use the services of any frequency coordinator certified to coordinate frequencies in its pool of eligibility. Contact numbers for all four coordinating bodies are given in resources, appendix D.

The application form for radio licenses is FCC Form 600 for two-way radio frequencies (soon to be replaced by FCC Form 601). For FCC microwave frequencies, the application is FCC Form 415. Forms are available from the FCC or may be downloaded from its Web site.

In addition, if one of your base, repeater, or microwave stations requires a tower or an antenna tip with a height of 200 feet or more, you will need to complete a Federal Aviation Administration (FAA) Form 7460-1. If your antenna is within 5 miles of an airport runway and its height (in feet) is greater than or equal to 40 times the distance to the runway (in miles), you will also need to complete the same form.

If you are purchasing communications services from a licensed vendor, you will not have to obtain licensing. If you are sharing a system with another agency, make sure that the other agency is licensed. Normally, a letter contract or a memorandum of understanding (MOU) is drawn up between the licensed agency and a user.

FCC Rules and Regulations

Part 90

Part 90 covers the Rules for a number of *private land mobile radio services* including those for public safety. This section specifies the frequencies available for the various private and public safety services, licensing information, and technical and operating requirements. Technical rules include types of modulation, bandwidths, interference criteria, power output, and antenna height data.

Licenses require frequency coordination. Public safety agencies generally must use APCO for coordination. No Federal fees are required for license applications from local government applicants.

Docket 92-235. In FCC Docket 92-235, adopted in February 1997, the FCC reduced the number of service pools for frequencies below 512 MHz to two:

1. *Public safety*, consisting of local government, police, fire, highway maintenance, forestry conservation, emergency medical, and special emergency.

2. *Industrial/business*, consisting of power, petroleum, forest products, film and video production, relay press, special industrial, business, manufacturers, telephone maintenance, motor carrier, railroad, taxicab, and automobile emergency.

Certified frequency coordinators for the particular services are still required to assign frequencies for these services. The FCC also authorized centralized trunking at allocated frequencies from 150 to 512 MHz, providing no harmful interference is caused to existing channels.

Part 22

Part 22 of the Rules covers the licensing and technical requirements for *common carrier mobile radio services*, including paging and radio telephone services, rural radio telephone service, and cellular radio.

Public safety agencies may use these services as subscribers only; the licenses are held by the service providers.

Part 24

Part 24 covers the Rules for personal communications services. This unique set of Rules deals with the auctioning of frequencies in the 900 MHz and 2 GHz bands. There is little technical detail, since winners of the auctions may provide many different types of service within the areas where they have won licenses.

At this time, the majority of 2 GHz PCS licensees are providing cellular voice services similar to those in the cellular radio frequency band.

Part 101

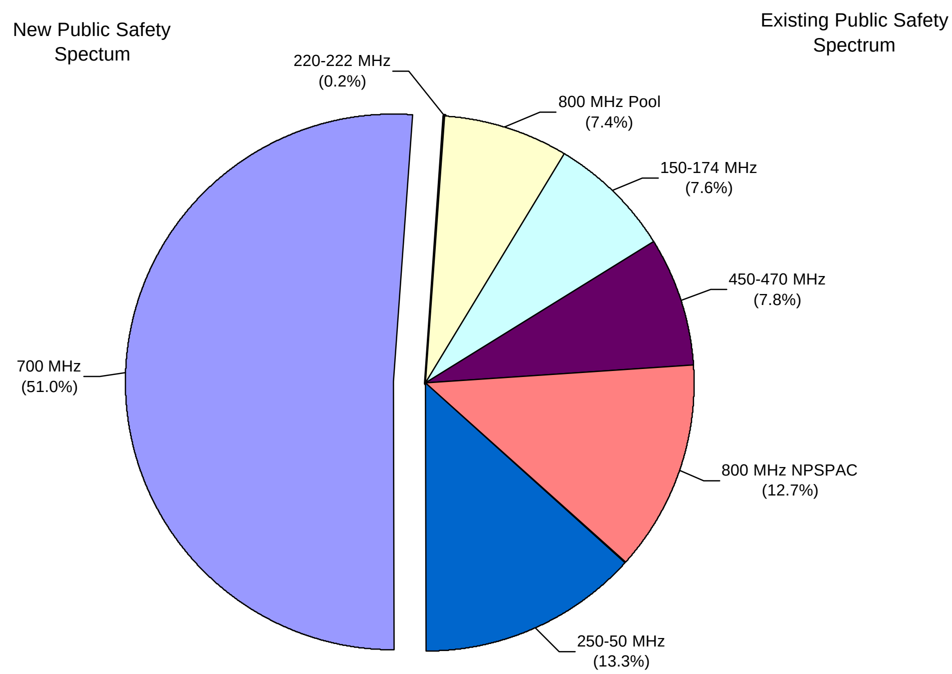
Part 101 covers microwave point-to-point radio frequencies. Frequency coordination, licensing, and technical standards are identified.

Frequency Reallocation

A study was made by the public safety community, which declared its current need for additional spectrum due to crowding and interference, as well as identified future requirements for interoperability and broadband initiatives. As a result, the FCC, in December 1997, reallocated television channels 63 and 64 (764-776 MHz) and 68 and 69 (794-806 MHz) for public safety communications (Docket 96-86). The net effect will be to double the amount of spectrum available for public safety communications (figure 8-1).[6] Frequency plans and the implementation schedule are being worked on by the FCC at this time.

[6] "FCC Allocates More Spectrum to Public Safety," *Government Technology* (March 1998): 12.

Figure 8-1. Public Safety Spectrum Doubles



Refarming

The "Part 90 refarming" was officially adopted by the FCC in several dockets:

Docket 92-235 (6/15/1995).
Docket 92-935 (12/23/1996).
Docket 92-235 (2/20/1997).[7]

The purpose of this initiative is to reduce most of the bandwidths of Part 90 radio systems operating below 512 MHz, thus promoting an increased efficiency in use. The reduction is in two stages: first from 25/30 KHz to 12.5/15 KHz and then from 12.5/15 KHz to 6.25/7.5 KHz bandwidths over a period of time. Licensees will not be required to replace their equipment to meet the band reduction requirement.

Currently, manufacturers are required to supply new equipment meeting the 12.5/15 KHz bandwidth specification, allowing for a smooth changeover. The bandwidths must be halved by manufacturers again by January 1, 2005. More details regarding refarming may be found in the footnoted references.

[7] Ericisson, *Refarming - Truths and Myths* (brochure), February 1998.

Chapter 9

Radiofrequency Electromagnetic Radiation Exposure

The FCC Office of Engineering and Technology (OET) Bulletin 65, *Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields* was upgraded in August 1997 to ensure the protection of human beings working around or near radio-transmitting facilities. The compliance is divided into two parts—one for "occupational or controlled exposure" and one for the "general population or uncontrolled exposure." OET Bulletin 65 is available for downloading at www.fcc.gov/oet/rfsafety. All existing transmitting facilities and operations must be in compliance with the regulations by September 1, 2000.

Table 9-1 shows a chart with the maximum permissible exposures in each category. The basis for the chart is the thermal effect of radio frequency (RF) energy on human tissue. The worst frequency for RF absorption is in the 100 to 300 MHz range. At that frequency, the highest RF level in controlled areas is 1 mW/cm^2 for 6 minutes of exposure time and $200 \mu W/cm^2$ in uncontrolled areas for 30 minutes of exposure time.

Calculations are explained and examples are given in the OET Bulletin. At the time of initial license applications and renewals, a licensee must certify that these conditions will be met. This may require that transmitter output powers be reduced or that transmitters be turned off while technicians work near transmitters or climb towers.

At multiple transmitter sites, the contributions of each system must be calculated and then are added together to determine if the site meets compliance. At sites where there are many transmitters and antennas over large frequency ranges, calculations may become too difficult to perform accurately, and actual measurements may have to be made.

Table 9-1. **Abbreviated Maximum Permissible Radiation** **(From FCC OET Bulletin 65, August 1997, p. 67)**		
Frequency Range in MHz	**Maximum Controlled Area Exposure (mw/cm^2) for 6 minutes**	**Maximum Uncontrolled Area Exposure (mw/cm^2) for 30 minutes**
30 - 300	1	0.2
300 - 1500	f/300	f/1,500
f = frequency in MHz. mw/cm^2 = milliwatts per square centimeter.		

Chapter 10

FBI NCIC 2000

The FBI's National Crime Information Center (NCIC) computer provides all 50 States with access to the records in the databases. Currently, more than half a million users in some 80,000 agencies make 1.7 million inquiries per day to NCIC.[8] Harris Corporation has been awarded a contract to upgrade the NCIC system, which includes replacement of the old computers with new IBM® 390 mainframes and operating systems. Projections call for up to 2 million transactions per day.

The NCIC 2000 project expects to support communication with mobile-imaging units in patrol cars.[9] The upgraded system will require that communicating units use TCP/IP over X.25 protocol before the system is placed online. After many users' requests, the FBI is considering other protocols such as TCP/IP over point-to-point protocol (PPP), Ethernet, and additional options. The FBI has conducted tests using various communications technologies, including CDPD, 800 MHz alone, and 800 MHz in conjunction with microwave.

An NCIC 2000 workstation has been developed for mobile-imaging units to transmit and receive mug shots and fingerprints. Plans call for high-quality imaging, including mug shot field imaging with high- quality field cameras so that officers may simply point and click. A quick check of a right index fingerprint will be possible with the fingerprint-matching subunit planned for use in the system. When the system is complete and operational, a field officer will be able to:

- ➡ Enter a wanted person's fingerprint, mug shot, and identifying images.
- ➡ Identify a wanted person using a fingerprint.
- ➡ Modify a fingerprint entered into NCIC 2000 with a new fingerprint.
- ➡ Link a wanted person's fingerprint to one entered by another organization.
- ➡ Cancel a wanted person's fingerprint.
- ➡ Receive ownership of a linked fingerprint when the original owner canceled the entry.

[8] "FBI Readies New Crime Information Network," *Government Technology Reseller* (March 1998): 30.

[9] Ibid.

The NCIC workstation and the MIU (mobile imaging unit) will be based on Intel's Pentium technology. The most recently published (April-May 1998) minimum specifications for NCIC 2000 workstations required the following:

➡ Pentium processor.

➡ 16 MB memory.

➡ Storage capacity in the gigabyte range (minimum of 120 MB for the NCIC 2000 applications).

➡ RS232 serial port (based on the 16550 Universal Receiver/Transmitter [UART] chip for communications with the MIU).

➡ Monitor capable of displaying 1024 x 768 pixels and 64 gray shades with a Windows® driver and video card.

➡ Two-button mouse (Microsoft® compatible).

➡ Extended 101-key keyboard.

➡ 3.5-inch floppy disk drive (CD-ROM drive also recommended).

➡ Adaptec® SCSI board or comparable.

➡ One ISA slot for a communications board (EICON® X.25 configured under TCP/IP).

In addition to the above specifications, the FBI has published requirements for peripheral equipment (printers, scanners, dataradio modems, etc.), commercial off-the-shelf software (COTS), and NCIC 2000 workstation applications software (to be provided by the FBI to the States at no cost).

All of these specifications, as well as the latest status on the testing and implementation of the NCIC 2000 project, may be found at the FBI Web site or by contacting the FBI directly (see resources in appendix D).

PART 4

WIRELESS COMMUNICATIONS OPTIONS

This section looks at the options public safety agencies have for wireless communications, including the purchase of their own radio components and systems. The authors also have included examples in which local governments have used commercial services.

One special case is described in which a tower and radio supplier provided radio communications to a town by entering into an agreement to use some of the town's high-elevation real estate for commercial radio development in return for dedicated government radio systems.

Examined are the many commercial voice and data services available to law enforcement, including cellular and PCS, CDPD, SMR/ESMR, and data networks.

Networks are complicated. They consist of three generic components—hardware, software, and middleware. Hardware consists of radios, modems, and laptop computers; software is the programming that runs the radio controllers, modems, and laptop computers; and middleware is the (software) glue that interconnects all the components together. Middleware must be selected that supports the required hardware and software protocols.

A reminder: All radio systems should be carefully checked to make sure they have the coverage you need. If you are purchasing a new system, make sure that the supplier gives you written assurances that the system meets your needs. If you need to communicate with handheld radios in reinforced concrete buildings, make sure the supplier knows and makes calculations taking that into account. There are independent consultants who also can perform these calculations if you need a verification check. If the radio network is already constructed, borrow or rent equipment from the supplier and make sure the coverage satisfies your requirements.

Chapter 11

Voice Systems

Dedicated Radio Systems

Dedicated public safety radio systems include all radio technologies, ranging from conventional FM simplex and repeater systems to very complex and expensive trunked wide-area analog and digital radio systems at all of the two-way frequencies.

There are many suppliers for public safety radio systems. Three companies, however, have supplied and continue to supply the majority of public safety radio systems: Motorola, ComNet Ericsson, and the E.F. Johnson division of Transcrypt.

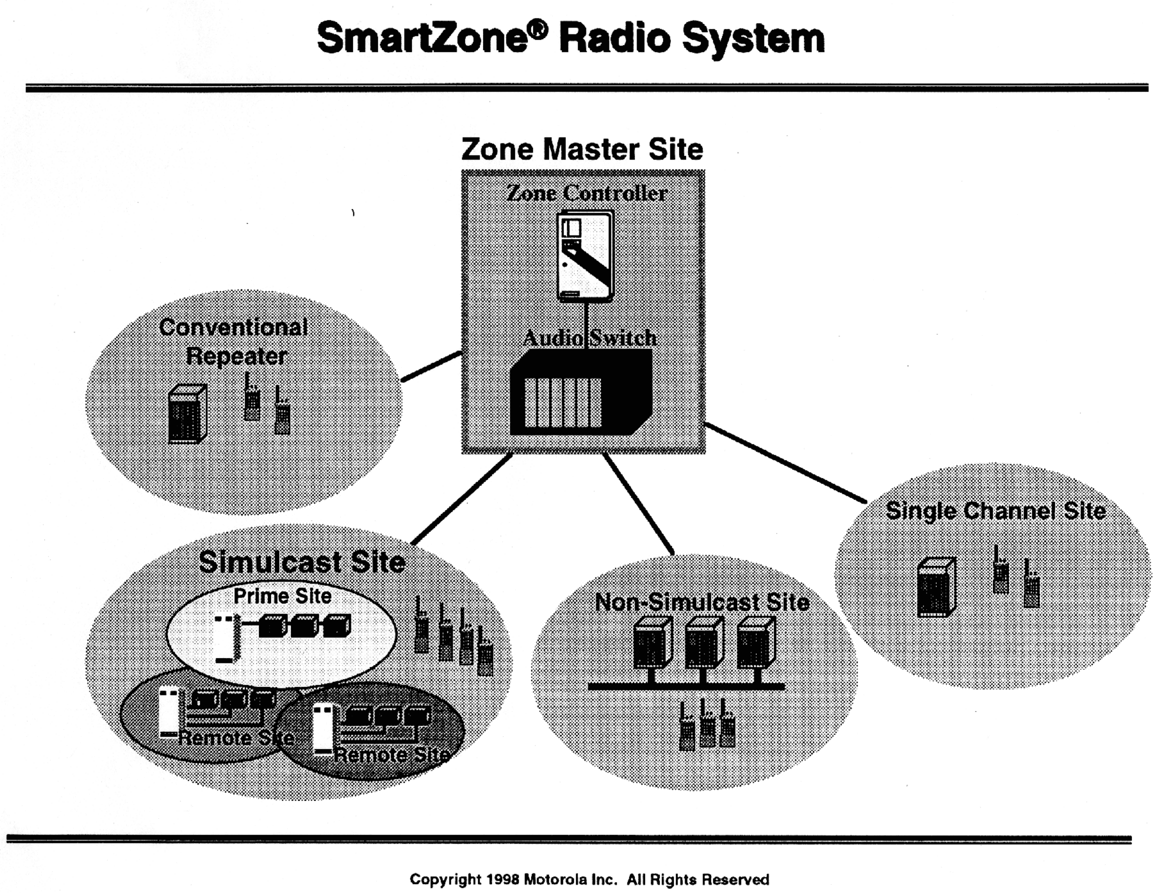
The three major companies had representatives on the Project 25 Committee, which selected the first phase digital trunked system technology standard to carry public safety communications into the next century. The Motorola protocol was selected for the first phase, and Motorola has offered its intellectual properties, royalty free, to other suppliers to allow competition. A large number of suppliers are developing systems using the new standard.

There are many other smaller suppliers of FM equipment, and some are supplying narrow band systems for the 220 MHz frequency band.

Sample Vendors

Motorola, Inc. Motorola offers some very sophisticated digital radio networks, as evidenced by its SmartZone® system, which can be configured for conventional repeaters, single or multiple site trunked repeaters, and/or simulcast trunked repeaters, as shown in figure 11-1. The company is currently upgrading the radio and dispatch systems for the city of Los Angeles.

Figure 11-1. SmartZone® Radio System Configuration



ComNet Ericsson Critical Radio Systems. In January 2000, Ericsson announced it was selling its private radio systems operations to ComNet Critical Communications, with the company renamed ComNet Ericsson Critical Radio Systems. ComNet Ericsson's main line of equipment for public safety is its enhanced digital access communications system (EDACS). EDACSs are used in trunked repeater systems including wide-area simulcast coverage. ComNet Ericsson has stated recently that it will begin to address and manufacture more conventional radio system products tailored toward the small law enforcement agencies around the world.

E.F. Johnson Division of Transcrypt. Transcrypt offers both conventional and trunked analog and digital radio systems. Its Multi-Net II trunked platform provides single-site, multisite, and wide-area simulcast solutions that are APCO Project 16 compliant. In addition, it offers digital Project 25-compliant radios, as well as analog portable equipment that is compatible with Motorola's SMARTNET II and SmartZone® systems.

Advantages of Dedicated Systems

1. Public safety entities may generate specifications to meet their exact system needs. They have complete control of the design and operations.

2. As part of the tailoring, the priority of use may be established within the entity.

3. Combined dedicated radio systems (i.e., shared with other communities) may save considerable investment and still preserve the tailoring at a more reasonable cost per agency.

Disadvantages of Dedicated Systems

1. The capital outlay may be quite high and prohibitive for a small to medium-size community.

2. The owner of the system must pay for all maintenance and improvements.

Cellular and PCS Radio

Many law enforcement agencies are already using cellular radio systems in addition to their dedicated radio systems for the transmission of voice messages. Almost all urban and suburban areas in the United States are covered by one or more cellular providers, although in sparsely populated areas, coverage may not be available.

In addition, the construction of personal communications systems (PCS), most of which are cellular systems in the 2 GHz band, has proliferated in higher density areas, and these systems are competing directly with 800 MHz cellular communications systems. There are as many as nine different technologies being used by different suppliers of cellular and PCS radio, so, once a user has chosen a company and handsets, it may be stuck with that supplier until the end of the contract.

System Coverage

System coverage is a major consideration in selecting a cellular system or PCS. The first thing to do when you think you want cellular or PCS service is identify the suppliers in your area. Contact them or go to the Internet and obtain a coverage map for your area for each supplier as well as its prices and terms. Borrow phones from suppliers and test different systems, where available, to determine which one covers your needs best.

☞ Try this...

Identify wireless carriers in your area at CTIA's Web site:

http://www.wow-com.com

Pricing

With the advent of increasing competition in many areas of the United States, the pricing packages are changing rapidly, so you will need to get the latest information at the time of purchase. Law enforcement may have an advantage in negotiating with suppliers since it is a highly visible public agency.

Sample Vendors

AT&T Wireless Services. AT&T has cellular and PCS licenses for most of the States in the country. However, they are not licensed in Montana, North Dakota, parts of Minnesota, Wyoming, or Texas. To determine if they provide coverage in your area, it is best to get the actual current coverage maps showing the specific area of interest. (Most can be obtained from the AT&T Wireless Services Web site, http://www.attws.com.)

Sprint®. Similarly, Sprint has almost all the Nation licensed for PCS coverage, but it is building its network in the highest density areas first, where it can most easily attract a large number of subscribers.

Advantages of Cellular/PCS Radio

1. Where there is coverage, subscribers should be able to contact any field or fixed personnel, regardless of agency or jurisdiction (i.e., supports a high level of interoperability).

2. Pricing is competitive in most areas.

3. Service can supplement dedicated radio communications.

4. With digital protocols used by many cellular/PCS radios, listening by unauthorized scanners is limited or eliminated.

5. Under certain emergency conditions, some vendors can supply portable cell sites to the scene to provide for increased cellular radio traffic.

Disadvantages of Cellular/PCS Radio

1. Coverage is limited or nonexistent in sparsely populated areas.

2. Most systems competing in local areas use different modulation techniques so that a particular handheld phone may not work with any other system.

3. In some locations, cellular radio systems are prone to overload in emergency situations.

A Special Case:
Conventional Radio System for the Township of Upper St. Clair, Pennsylvania

Upper St. Clair, a Pittsburgh suburb, has a unique problem of having deep narrow ravines throughout the township, making full radio coverage with its 460 MHz law enforcement system impossible. Patrol cars were unable to communicate with headquarters on roads at the bottom of some of these ravines. Also, the radios were installed years before, required excessive servicing, and were overdue for replacement.

The town did have one asset. The town's communications tower was in a high city park, overlooking much of Pittsburgh, making it an attractive site for other radio systems. The township was approached by Crown Communications, a commercial radio enterprise, to enter into a contract to install a new radio system and tower for the town's law enforcement communications, providing Crown could use the tower for commercial communications.

Crown used a computer propagation model to predict that, by replacing the present police system, with its antenna at 180 feet above the ground, with a new antenna with a down-tilt radiation pattern at 350 feet above the ground at the same location, a 460 MHz communications system would have practically full township coverage.

St. Clair officials recognized a good offer when they saw one. At no cost, Crown provided St. Clair with a new 350-foot tower (with police repeater antenna and room for expansion), a new base station, new mobile units, and new handheld radios. In addition, St. Clair got a zero-cost radio unit maintenance plan, as well as a small monthly lease income for making the site available and for allowing the company to construct a communications facilities building and install a number of commercial systems.

In a single "win-win" contract, St. Clair solved both its obsolete equipment problem (at no cost) and its coverage problem (tests showed the new system had excellent coverage, even at the bottom of the ravines).

Although deals as sweet as St. Clair's may not come along every day, your community may have assets that could lead to a similar "horse-trade" for equipment or commercial services.

Voice—SMR/ESMR

When the FCC wrote the trunked radio Rules, it provided for licensing specialized mobile (trunked) radio service companies (SMRs) to provide leased two-way mobile radio service. As time passed, with the development of digital radio trunking systems called "enhanced specialized mobile radio" (ESMR), greater spectrum efficiency was achieved. These systems use the 800 and 900 MHz portions of the radio spectrum.

Many SMR/ESMR systems are extremely reliable and are well suited for use by public safety agencies. SMR/ESMR systems work well for radio dispatch and for interconnection to the public telephone system. Offerings are usually competitive with other available mobile radio services.

Sample Vendor—Nextel

One ESMR provider with national coverage is Nextel (although, like the cellular/PCS providers, its presence is spotty in small-population areas). Nextel's system uses Motorola's iDEN equipment.

The system is quite similar to that of cellular radio; however, in addition to making phone calls, Nextel offers paging and dispatching services whereby a subscriber may call another mobile station or a group of stations on company-owned repeaters. The service allows for full duplex communications. Thus, one device gives you the capabilities of both a cellular phone and a handheld radio.

Services. Some of the specific Nextel services that may be of interest to law enforcement agencies are:[10]

1. Dispatcher to a single mobile station voice communications.

2. Dispatcher to a group of mobile communications.

3. Fast delivery paging and messaging so that a police officer may receive an alphanumeric message within 30 seconds and be able to acknowledge receipt. Using this kind of messaging may provide a minimum number of interruptions for officers on a beat.

4. Mobile-to-mobile private communications.

5. Mobile-to-PSTN telephone system for local and long-distance telephone calls.

6. Talk groups may be customized and private conferences arranged. A SWAT group may take advantage of this kind of communications.

7. Customized billing allows administrators to see exactly who is using the system, so they may control costs.

Nextel has several models of handsets, and you must use one made by the company.

Five types of dispatch calls may be made with Nextel's system: private calls, call alerts, local service area group calls, selected service area group calls, and wide-area group calls.[11]

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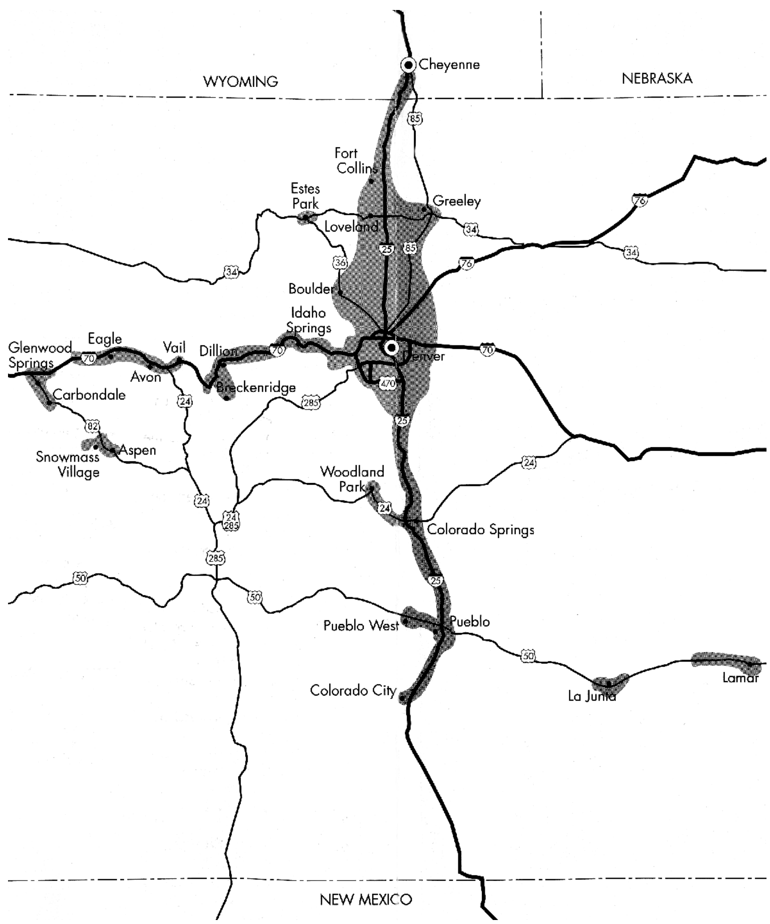
[10] "Nextel Benefit" sheet, supplied by Nextel in April 1998, private communications from Robert Kuck, Major Account Executive.

[11] Nextel, *Overview of iDEN*, R01.04.02, April 24, 1997, p. 3.

System coverage. Coverage of the nationwide system is restricted. As an example, figure 11-2 provides a typical coverage diagram for Colorado. You can see the radio system covers the major cities in Colorado, as well as major arteries in the State, but rural areas are virtually uncovered. Information on the coverage in this and other areas can be obtained at Nextel's Web site, http://www.nextel.com.

Pricing. The prices vary from location to location and are subject to change. Pricing is usage based, so it will vary by the anticipated and/or actual time used. Up-to-date information may be obtained from the Web site or directly from the company.

Figure 11-2. Nextel Sample Coverage Diagram for the State of Colorado (1998)



(Diagram courtesy of Nextel)

Sample Vendor—Lower Colorado River Authority

The Lower Colorado River Authority (LCRA) is a conservation and reclamation district in Texas that monitors and controls portions of the Colorado River. LCRA has a very extensive ComNet Ericsson EDACS digital radio system with extra capacity available for leasing to other utilities and, most recently, to public safety organizations.

When the San Marcos, Texas, Police Department's proposal for a $3.5 million upgrade for its radio system was rejected by the city council, the department needed to find a less costly alternative. LCRA provided a convenient option. The Authority supplied a new communications tower and a seven-channel trunked (EDACS) 900 MHz radio system within San Marcos. The city council approved $700,000 for the purchase of about 300 new mobile and portable radios, plus four new dispatch consoles. It also arranged for the installation of a T1 circuit to link the city communications center to the trunked repeaters.

San Marcos currently uses the radio system for voice transmissions. However, it will be installing laptop computers in squad cars in the near future. The city is evaluating new software for the dispatch center, which will allow laptops to communicate directly with NCIC.

San Marcos is paying LCRA a flat channel fee of $19.95 per month per mobile unit and $9.99 per month for each portable. LCRA takes care of all maintenance at its trunked facility.

Although LCRA will not prioritize public safety traffic along the network, when the first San Marcos emergency (27 inches of rain fell in October 1998) pushed the number of radio transmissions up from a normal average of 16,000 per day to 41,000 per day, the system operated well, with only a few minor hitches.

Advantages of an SMR/ESMR System

1. Capital expenses are amortized in monthly invoices and spread over the total customer base of the company.

2. Many modes of operation are available by using this service, as discussed above.

Disadvantages of an SMR/ESMR System

1. The agency must purchase special telephone/radio units.

2. Prioritizing transmissions for public safety agencies is generally not provided at this time. In case of an emergency, public safety agencies may not be preferred customers.

3. Flat rate billing may not be provided. Rates are commonly based upon a fixed fee plus usage.

4. The service may not be available in your area.

Chapter 12

Wireless Data Systems

Data transmission requirements of local public safety agencies continue to increase as computer-to-computer communications needs spread. Today, agencies need rapid radio access to governmental databases to obtain relevant information about vehicles, drivers, histories, hazardous material storage areas, and so forth.

Laptop computers are becoming standard equipment in vehicles to allow for accurate and quick inquiries. These computers may be connected to almost any radio system, with the proper modem. Agencies have used and continue to use dedicated, agency-owned radio systems for data, both conventional and trunked. However, increasingly commercial options have appeared in the marketplace. One such system (described below), which has become more and more popular, is cellular digital packet data, with expanded offerings in many parts of the country.

Regardless of the type of radio system used for data transmission, software also is required for these systems to work properly. Software on the laptop (usually licensed on a per-PC basis) and software back at the main computer site must both be present and be able to talk to each other over whatever backbone you select. The effective speed of your data network will depend heavily on the efficiency of the software used to pass the data back and forth.

Cellular Digital Packet Data (CDPD)

If you are planning on transmitting data for dispatching, for license and criminal record information, or for writing accident reports, CDPD may be the technology to use. CDPD uses packet radio hardware and software and is regularly used with laptop computers or mobile data terminals. CDPD may be available from a cellular supplier in your area. Some CDPD suppliers with interesting offerings are described in the following section.

Sample Vendors

AT&T Wireless. AT&T Wireless Services developed a white paper in 1997 titled “CDPD for Public Safety,” outlining the use of CDPD by law enforcement agencies. The document includes information on the wireless environment applicable to public safety dispatch users and the economics for CDPD usage. It compares CDPD with the other options available to public safety organizations for the transmission of wireless mobile data, including government-owned voice- and data-dedicated private mobile radio systems, specialized mobile radio (SMR) trunked radio systems, and public networks.[12] Note that the document is a marketing piece and, thus, tends to downplay the disadvantages of CDPD, but not unfairly.

AT&T is offering CDPD service for public safety use on a fixed-price per vehicle per month schedule; other providers have not yet followed suit.

The McKinney Police Department (near Dallas, Texas) is using AT&T CDPD and claims to have saved close to $500,000 by using AT&T's wireless network. The department equipped its patrol cars with laptops, modems, and other necessary equipment. The city is using the network to obtain history reports on domestic violence and to perform criminal and vehicle checks.[13]

Bell Atlantic Mobile. Bell Atlantic Mobile offers their Airbridge® service using CDPD to access the Internet as well as corporate or local government internal computers for database inquiries.

The Metropolitan Police Department of Washington, D.C., uses Airbridge®, and patrol car personnel regularly access criminal databases and motor vehicle records using laptop computers.[14]

GTE Wireless. GTE offers an "Intelligent Patrol" turnkey package that bundles together hardware (including a ruggedized laptop computer and modem), software and service, training, installation, integration, and maintenance, with a leasing option.[15] The laptop computer can handle inquiries to criminal databases, warrants, and mug shots. Besides retrieving information, laptops can also dispatch using CDPD. GTE offers usage-based pricing on its service.

Advantages of CDPD

1. The service is available in many areas in the United States and is ideal for applications involving short rapid data exchange. Police officers can readily access local, State, and national databases from their patrol cars.

2. The capital expenses are only for computers, modems, and software. The communications network is provided by the cellular service provider, so entry costs for agencies are quite low.

3. Information may be obtained quickly from database resources, including NCIC, without the need to extend time to go through a dispatcher.

[12] Vlcek, Charles, "CDPD for Public Safety," AT&T White Paper, May 29, 1997.

[13] *Wireless Week* (June 1, 1998): 28.

[14] *Radio Resource Magazine* (June-July 1998): 46.

[15] Ibid, p. 48.

4. The accuracy of the information may be better if it is directly obtained from a law enforcement database without any voice involved.

5. Industry standard TCP/IP protocols make the connection with standard databases.

6. Some service providers are willing to prioritize traffic on their CDPD networks so that law enforcement may be able to displace noncritical traffic during emergencies.

7. Hardware and software are available from multiple sources, allowing for competitive bids in a community where there is more than one source.

8. CDPD can act as a backup communications network if the primary law enforcement radio communications network goes down.

Disadvantages of CDPD

1. CDPD cell coverage may be limited or not available in sparsely populated communities or rural areas.

2. There may not be enough capacity to handle law enforcement requirements during a heavy rush for information.

3. The maximum data rate is 19,200 bps, which may not be satisfactory for obtaining high-quality fingerprints or complex mug shots quickly.

4. In large agencies with a large number of vehicles, the cumulative cost of CDPD service could exceed the cost of a dedicated radio infrastructure.

5. Some service providers will not prioritize traffic for public safety users.

Private National Data Networks

At this time, there are two private national data networks: ARDIS and RAM. Both networks offer data communications services within urban areas and between many cities across the continental United States, Alaska, and Hawaii.

Sample Vendors

Motient Wireless Data Network (founded as American Mobile Satellite Corporation). Motient completed its acquisition of the ARDIS mobile data network in March 1988. The company name was changed in April 2000. Motient has an extensive data network in more than 500 U.S. cities (including cities in Alaska, Hawaii, Puerto Rico, and U.S. Virgin Islands), providing services for in-building, on-street, and in-vehicle locations. Some 1,900 base stations are tied together to form a national backbone. PC, LAN, and mainframe systems can be connected to the Motient network via radio modems, dial-up, or dedicated leased lines.

The company now claims to provide services to many rural areas (90 percent of the U.S. area containing 80 percent of the population), much of which is not well covered by other wireless services. As a result, small public safety entities in remote areas may have a commercial option for obtaining database information from far-flung databases or for other computer or voice communications.

Packet data network technology is employed by the system. According to the company, the combined satellite/terrestrial network allows the company to optimize the transmission of data by using both terrestrial and satellite paths, thus minimizing their costs.

Services provided by the company include:

1. Wide-area two-way voice and messaging services.
2. Telephone interconnect.
3. Digital voice dispatch.
4. Data communications.
5. Position reporting services.
6. Internet messaging.

The system can employ a number of different hardware configurations, including laptop and palmtop computers with appropriate wireless modems. The system is software and middleware driven. Compatible software and hardware are supplied by a number of vendors. Motient has nationwide contracts with organizations such as AT&T, Pitney Bowes, IBM, Avis, Sears, and Otis Elevator Company.

BellSouth® Mobile Data (RAM Network). BellSouth Mobile Data Corporation took over RAM Mobile Data in early 1998 and is expanding the number of base stations in metropolitan areas across the United States. According to BellSouth, "the primary objective of the RAM network is to send and receive messages and data from anywhere at anytime."[16]

The system is a data-only, packet-switched network and uses packets of 512 bytes transmitted at an 8 Kbps rate. Efficient addressing, automatic repeat requests, and forward error correction are used in the network making it 99.99 percent reliable, according to the company.

The base stations use transmitters with 200 watts ERP, and mobiles transmit with up to 2 watts. A multitude of trunked base stations are used throughout all the metropolitan areas in the United States. UHF SMR channels are used to transmit the data. The data are encrypted by scrambling the packets to provide privacy to customers and may be further encrypted by customers, if required.

[16] "RAM Mobile System Overview," Executive Summary, August 1995.

The service is based upon ComNet Ericsson's Mobitex® standard used throughout Europe. The network supports many data communications protocols including UDP/IP, TCP/IP, SNA/3270, X.25, asynchronous, and MPT/1 transport protocol.[17]

The network can perform the following tasks:

1. Transmit and receive messages and pages, including inquiries to databases.
2. Allow transmission of group messages.
3. Respond within 6 to 10 seconds to the pages and messages as a positive acknowledgment.
4. Send text-to-voice messages.
5. Query Web sites.
6. Send faxes.
7. Send and receive e-mail.
8. Connect to PSTN to dedicated lines or to the Internet.
9. Store and forward messages for up to 72 hours.

To operate on the RAM network, an agency needs laptop or palmtop computers, application software supported by appropriate middleware, a wireless modem, and BellSouth's RAM wireless two-way data transmission service. BellSouth provides open interfaces that enable many vendors to supply hardware, software, and system integration services.

Coverage information may be obtained from the company's Web site. As said previously, an agency is encouraged to perform its own coverage testing before making a commitment for the use of the network.

Information on the system may be obtained by calling BellSouth or by visiting its Web site.

Advantages of Private National Data Networks

1. Network store and forward. Packets may be stored for sending at a later time.

2. Companies guarantee fast network response and delivery of data, within seconds of being transmitted.

3. Both companies provide encrypted service, if desired.

4. Costs are proportional to usage.

Disadvantages of Private National Data Networks

1. The two national data networks do not yet support data rates in excess of 8 kbps.

[17] "MOBITEX Features and Services," RAM Mobile Data White Paper, February 1997.

2. Because these are packet networks, with 200 to 1000 bits per packet, they are not very efficient for long messages. They need to be used for files of less than 10,000 bits.

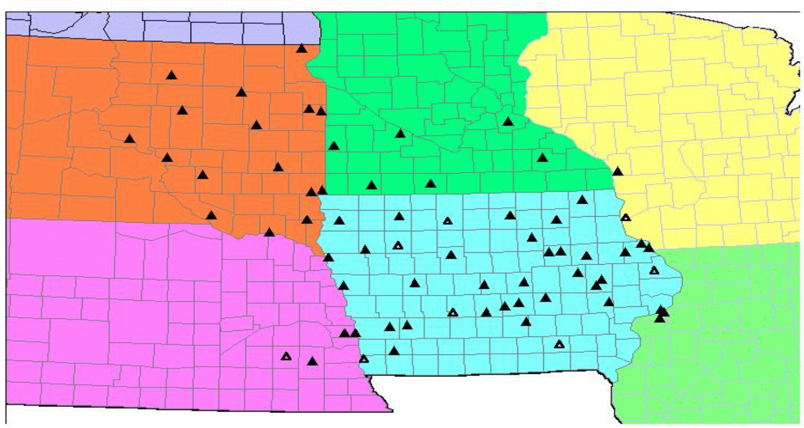
Regional Voice and Data Systems

A number of ESMRs provide digital radio systems for both voice and data traffic. One is discussed below. Other communications and utility companies across the country have offerings for the provision of regional communications.

Sample Vendor

RACOM. RACOM, headquartered in Marshalltown, Iowa, operates a large 800 MHz trunked digital wireless network and boasts of some 6,000 customers in Iowa, Minnesota, Nebraska, South Dakota, Wisconsin, and Illinois with some 4,000 contiguous channels (see figure 12-1). The company's core business consists of wireless voice and data services for public safety, utility, and industrial customers. By combining the needs of many entities on a common network and providing a high level of network maintenance, RACOM claims that users can avoid substantial cash outlays while experiencing a high degree of system reliability and flexibility.

Figure 12-1. RACOM EDACS Network in Six Midwestern States (diagram courtesy of RACOM)



The backbone network consists of ComNet Ericsson's EDACS system; however, the company is now constructing an additional network using Motorola's iDEN technology. One major advantage of RACOM's network for public safety is that it provides interoperability to governmental customers.

For example, the cities of Moline and East Moline, Illinois, put out bid requests for dispatch centers and radio equipment for their police, fire, emergency medical, and public works departments. Two bidders responded. One proposed two dispatch centers; the other, RACOM, proposed a combined center. The RACOM proposal offered each department in each city separate frequencies for specific talk groups and offered clear channels for intra-city communications when required.[18] The cities went with the RACOM plan, thus saving the money to be spent on a second center.

RACOM provided the Fort Dodge (Iowa) Correction Facility with the capability for transmitting voice, data, dispatch, and vehicle-tracking signals. Of special concern was the plausibility of being able to transmit and receive signals within all areas of the prison. RACOM established a transmitting facility within a half mile of the prison, and, as a result, there are no dead spots within the prison facility.[19]

Besides RACOM's public safety customers mentioned above, as of 1999, the company serviced Black Hawk County, Iowa; Dubuque County, Iowa; Polk County, Iowa; Sioux City, Iowa; Lincoln, Nebraska; Milan, Illinois; Rock Island Arsenal, Illinois; Yankton, South Dakota; city of Waterloo, Iowa; and the U.S. Army Corps of Engineers. Additionally, RACOM has commercial customers including Deere & Co., General Mills, Rockwell International, MidAmerican Energy, Utilicorp, and East River Electric.

Advantages of Regional Voice and Data Systems

1. Lower capital outlay by sharing existing system.

2. Maintenance is taken care of by the system supplier.

3. Capital expenses are amortized in monthly invoices and spread over the total customer base of the company.

4. Many modes of operation are available by using this service, as discussed previously.

Disadvantages of Regional Voice and Data Systems

1. Law enforcement agency does not have complete control over the system.

2. The agency must purchase special telephone/radio units.

3. Prioritizing transmissions for public safety is often not provided. In case of an emergency, public safety agencies may not be preferred customers.

[18] SMR/Private Radio, "Agencies to Operate RACOM System," *Wireless Week* (March 30, 1998).

[19] Ibid.

4. Flat rate billing may not be provided by companies. Rates are commonly based upon a fixed fee plus usage.

5. The service may not be available in your area.

Chapter 13

Latest Developments

Mobile Satellites

Although it is uncertain as to when satellite communications will be practical and economical for use by public safety agencies, it is critical to discuss these important emerging technologies in this handbook.

The United States has a fleet of geosynchronous earth orbit (GEO) satellites at approximately 22,500 miles above the equator providing wideband transponders to connect telephone and television circuits around the world. There are several GEO systems used for general mobile services available today. However, they require a briefcase full of equipment, including a highly directional antenna. In addition, there is a delay of about 1/4 second for the transmission, which slows down interactive voice and data transmissions considerably. Because of this, the service is not yet appropriate for the use of simple handsets as used for cellular or PCS radio.

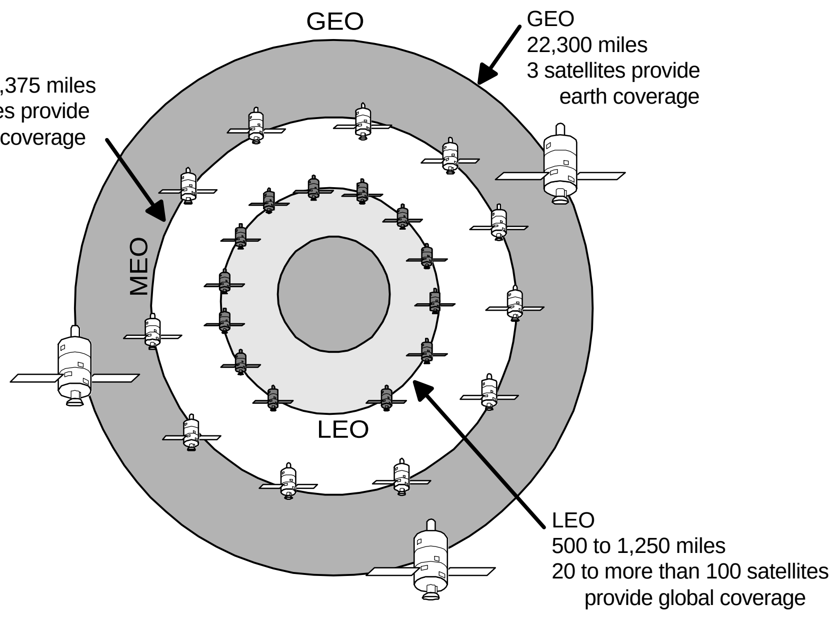
☞ Did you know?

LEO = low earth orbit
MEO = medium earth orbit
GEO =geosynchronous earth orbit

Voice Communications Satellites

Besides GEOs, medium earth orbit (MEO) and low earth orbit (LEO) satellites have been proposed for relaying radio transmissions. MEO and LEO satellites require less output power from phones and have less time delay than GEO systems. The relationship of GEO, MEO, and LEO satellites is shown in figure 13-1.

Figure 13-1. Mobile Satellite System Orbits



Reference: Public Safety Wireless Network, "Mobile Satellite Services (MSS) Report", p.8.

Example system—Iridium®. In 1987, Motorola engineers proposed their Iridium satellite system for wireless communications to allow a person with a small handset anywhere on the earth's surface to communicate with another person's handset anywhere else on the earth's surface. This satellite system is the first of a number of systems that not only receive signals from the earth (which are converted in frequency, amplified, and retransmitted as commonly done in transponders) but also contain switching and routing processors. The system consists of 66 satellites placed in LEO orbits and is carrying commercial traffic. However, as of February 2000, the company had filed for bankruptcy protection but continued to operate.

The Iridium system is composed of 6 planes of 11 satellites equally spaced in a low-elevation orbit with an orbit altitude of 421.5 nautical miles, as shown in figure 13-2.[20] Each satellite provides a set of 48

[20] Roddy, Dennis, *Satellite Communications*, 2nd Edition, New York: McGraw-Hill, 1989: 424.

separately controlled spot beams to cover the earth's surface so that (with the 66 satellites) there will be 3,168 cells covering the entire earth.

The system may be thought of as a type of cellular radio system where the "cellular base stations" and cells are constantly rotating so the earth signals are handed off from one satellite to another as they pass over an individual's handset.

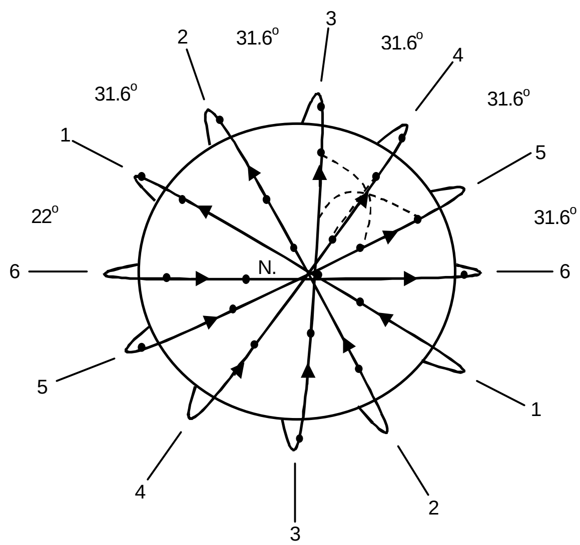


Figure 13-2. A polar view of the Iridium satellite orbits.

L-band frequencies (1616 - 1626.5 MHz) are to be used for the communications between the earth and the satellites and the Ka-band frequencies (23.18 - 23.38 GHz) are used for intercommunications between the satellites. Ground segment frequencies to gateways and control facilities use Ka-band frequencies (downlinks,19.4 - 19.6 GHz, uplinks, 29.1 - 29.3 GHz). Figure 13-3 shows Motorola's concept of this system.[21] Iridium will support voice and data up to 4800 bps.

[21] Ibid, p. 425.

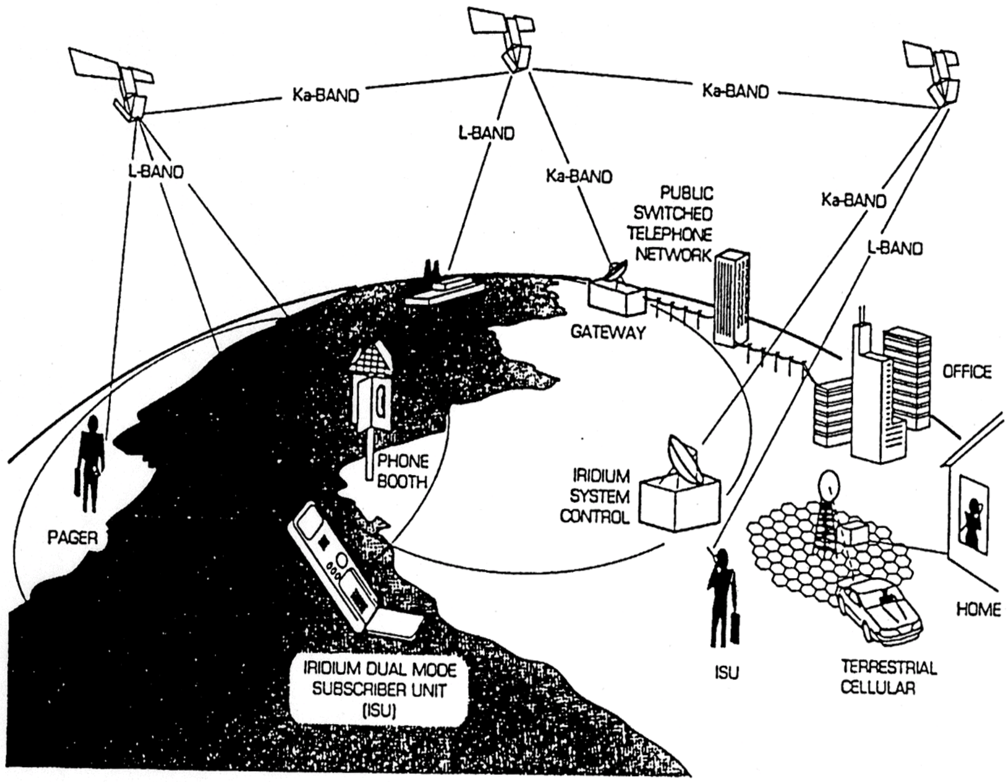


Figure 13.3 Iridium® system overview. (*Courtesy Motorola.*)

Services supplied by Iridium are:[22]

1. *Iridium Universal Service.* Multimode phone subscribers will communicate with terrestrial facilities when within their wireless areas; if outside, they will communicate using the 66 satellite Iridium system.

2. *Iridium Satellite Service.* Subscribers who are primarily outside of terrestrial service areas may subscribe to this service.

3. *Iridium City-to-City Service.* Subscribers who travel frequently to cities covered by wireless networks, with previously incompatible services due to differing protocols, may decide to use this service.

4. *Iridium Paging and Notification Service.* Subscribers needing alphanumeric worldwide one- or two-way paging services may subscribe to this service.

[22] Iridium Brochure, December 1997.

Other voice satellite systems. Although Iridium is the first PCS satellite system to be implemented, four other systems are being installed, as shown in table 13-1.[23] Two similar systems, Globalstar™ (being implemented by Loral and QUALCOMM®) and Constellation Communications, Inc.'s ECCOᴷ, are LEO systems with 48 and 46 satellites, respectively. As of February 2000, it appears that these companies are proceeding with their plans even though Iridium has filed for bankruptcy.

Mobile Communications Holdings' Ellipso™ and ICO Global Communications' ICO satellites are in MEOs, spaced at about 6,000 to 10,000 miles above the earth's surface.

Table 13-1. Voice-Oriented Personal Communications Satellite Systems

	Iridium	**Globalstar™**	**ICO**	**Ellipso™**	**ECCOᴷ**
Company	Motorola	Loral/QUALCOMM®	ICO Global Communications	Mobile Communications Holdings	Constellation Communications
Number of Active Satellites	66	48	10	14	46
Orbit Planes	6 circular polar (86.5 degrees)	8 circular inclined (52 degrees)	2 circular inclined (45 degrees)	2 elliptical inclined (116.6 degrees); 1 elliptical equatorial (0 degrees)	7 circular inclined (62 degrees); 1 circular equatorial (0 degrees)
Orbit Altitude (kilometers)	780 (LEO)	1,414 (LEO)	10,355 (MEO)	520-7,846 (MEO); 4,223-7,846 (MEO)	2,000 (LEO)
Satellites per Orbit Plane	11	6	5	4 per elliptical; 6 per equatorial	6 per inclined; 11 per equatorial
Beams per Satellite	48	16	163	61	32 per inclined; 24 per equatorial
Reported Cost (billions of dollars)	3.4	2.6	4.6	0.91	2.8

There are tradeoffs between the LEOs and MEOs. Far fewer satellites are required in the MEO system than in the LEO system, but higher effective power is required for transmissions by the subscriber units, and time delays are greater. With the exception of Iridium, service offerings by these companies have not been described in detail.

[23] Evans, John V., "New Satellites for Personal Communications," (278) 4 *Scientific American* (April 1998): 72.

Pricing of services has not yet been finalized, but it is estimated that prices will be in the range of $3 to $5 per minute. Almost all of these companies have Web sites. Visit those sites as the technologies develop to evaluate the use of satellite services as they become operational. Because of the large number of commercial providers for both voice and data systems, there will most likely be considerable competition when all of the systems are turned up.

Data Communications Satellites

Since 1992, American Mobile Satellite Corp. has offered SKYCELL® service employing geosynchronous satellites for communication of data up to 4800 bps. Both voice and data may be handled on the same system. One type of use of the SKYCELL® system includes mobile messaging services for large fleets that can be used virtually anywhere in North America.. The system uses “L-band” technology with antennas mounted in small domes on the roofs of vehicles to allow for two-way data transmission and position tracking. Interfaces use standard dispatch application software. The service may be used to send data reports, e-mail, and faxes, as well as to connect to the Internet.

With an OmniQuest portable satellite telephone, notebook computer, portable printer or scanner, and/or digital camera, public safety personnel can get in touch with national databases or headquarters. A dispatcher can open a voice channel and connect with one or a fleet of mobiles. Communications, according to SKYCELL®, are secure. Features include full duplex voice communications, up to 4800 bps data transmission, 24-hour customer service, voice mail, call forwarding, conference calling, call barring, and land line access to talk groups. SKYCELL® provides dual mode services allowing mobile units to use their terrestrial service when within their coverage area and to automatically switch over to satellite when the terrestrial system is not available.

Wideband, data-oriented LEO and MEO PCS satellites are being studied and proposed at this time, as shown in table 13-2.[24] These satellite systems will have the ability to carry high-speed data around the world at up to10 gbps.

[24] Ibid, p. 73.

Table 13-2. Data-Oriented Personal Communications Satellite Systems

	Astrolink™	**Cyberstar™**	**Spaceway™**	**GE*Star**	**Morning Star**	**Teledesic**
Company	Lockheed Martin	Loral	Hughes	GE Americom	Morning Star	Teledesic
Number of Active Satellites	9	3	20 MEO/ 16 GEO	9	4	288
Orbit Planes	Equatorial (0 degrees)	Equatorial (0 degrees)	4 inclined (55 degrees); 1 equatorial (0 degrees)	Equatorial (0 degrees)	Equatorial (0 degrees)	12 inclined (98 degrees)
Orbit Altitude (kilometers)	GEO	GEO	10,352 (MEO) and GEO	GEO	GEO	1,375 (LEO)
Estimated Satellite Capacity (gigabits per second)	6.0	9.0	4.4	4.7	0.5	10.0
Estimated Capital Investment (billions of dollars)	4.0	1.6	6.4	4.0	0.82	9.0

Note: Motorola has decided not to construct its Celestri™ network and has opted to purchase part of the ownership of Teledesic.

High Altitude Long Endurance (HALE) Platforms

In this proposed network, relay of signals would be accomplished using large blimp-like repeaters at several miles (20,000 meters) above the earth. The devices would cost less than the big satellite systems and could be recalled to earth for maintenance. Multibeam, phased array antennas would support both mobile two-way communications and broadband video.

Four types of HALE platforms have been proposed,[25] which include helium-filled, robotically controlled dirigibles stabilized by ion engines; units powered by solar or fuel cells; piston-driven platforms; and jet engine-driven platforms. The biggest challenge faced by all of them will be power requirements versus refueling requirements. The first two types need little or no refueling but may not produce the transmit power needed, whereas the latter two types will have plenty of power but will need to be refueled every few days.

Sky Station International was the commercial initiator of this technology in the United States and filed with the FCC in March 1996 for use of the 47 GHz band. Sky Station claims a blimp repeater can offer many advantages over satellites, including less time delay and lower power at a considerably lower cost. The concept was also introduced at the 1997 World Administrative Radio Conference, and a portion of the 47

[25] Pelton, Joseph N., “Telecommunications for the 21st Century,” (278) 4 *Scientific American* (April 1998): 85.

GHz band was tentatively allocated. The 47 GHz band is severely limited by rain, so space diversity ground circuits will most likely be required.

The basic concept is to have “very high antenna towers” allowing for very wide-area communications. This might be an alternative to backbone microwave terrestrial systems. Sky Station indicated that one could start with communications in local areas, expand to regional areas, and eventually cover the country. The FCC has made no decisions at this time. The concept has many technical and political challenges, and its development should be interesting to watch as it evolves.

SUMMARY

At no time in the history of public safety communications have so many options been available. Technological advances and regulatory changes have combined to make selecting a communications system very complex. As we move into the future, it is unlikely to get any better.

NLECTC–Rocky Mountain and other groups [such as the Federal Public Safety Wireless Network program (PSWN)] are dedicated to helping you through the maze of technology jargon and bureaucratic rules as you proceed on your communications project.

We hope this guidebook has been useful to you. We welcome your comments and suggestions for improvement.

GLOSSARY AND ACRONYMS

Glossary

Amplifier: A device for obtaining an increase in voltage, current, or power.

Amplitude: The maximum departure of the value of an alternating current or radio wave from the average value.

Analog: A signal that may vary continuously over a specific range of values.

Antenna: A device (usually metallic) for radiating or receiving radio waves.

Band: A well-defined range of wavelengths or frequencies.

Bandwidth: The range within a band of frequencies. A measure of the amount of information that can flow through a given point at any given time.

Bit: Abbreviation for binary digit (either a 0 or a 1), the basic unit for storing data in a computer.

Block grant: Federal grant funds that are allocated based on a predetermined statutory formula.

Cavity filter: A device used to shield the receiver from the transmitter and to form a circuit called a duplexer.

Channel: A band of frequencies of sufficient width to allow a single radio communication.

Combiner: A device used to combine the output signals from a number of transmitters connected to the same antenna (in trunked radio systems).

Coverage: The amount or percentage of area reached by a communications medium.

Cycle: One complete performance of a vibration, electrical oscillation, current alternation, or other periodic process.

Digital: Information that can be represented by two discrete states (either 0 or 1). Most information in the speaking/seeing world is not digital, but must be converted into this form to be used by computers.

Dipole: A radio antenna consisting of two horizontal rods in line with each other, with their ends slightly separated.

Discretionary grant: Federal grant funds that are distributed at the discretion of the agency administering the funds.

Duplexer: A switching device that allows alternate transmission and reception with the same radio antenna.

Effective Radiated Power: A term for describing radio power levels.

Flowchart: A diagram showing the step-by-step progression through a complicated process or system.

Formula grant: Federal grant funds that are allocated based on a predetermined statutory formula.

Frequency: The number of repetitions of a periodic process in a unit of time.

Frequency multiplier: A device for multiplying the frequency up to a desired output frequency.

Gain: The effectiveness of a directional antenna expressed as the ratio in decibels of standard antenna input power to the directional antenna input power that will produce the same field strength in the desired direction.

Guard band: A nonoverlapping space between radio channels used to minimize interference.

Hertz: Abbreviation for cycles per second.

Implementation team: A group of officials charged with ensuring that a project is planned, managed, and completed.

Infrastructure: The underlying permanent installations required for radio communications.

Interference: Confusion of received radio signals due to strays or undesired signals.

Isolator: A device that may be added to the circuit between each transmitter and the combiner and used to increase the isolation to the other transmitter outputs.

Isotropic radiator: A theoretical antenna that radiates equally in all directions.

Modem: An acronym for modulator/demodulator, which is a device that translates digital signals coming from your computer into analog signals that can be transmitted over standard telephone lines. The modem also translates the analog signal back into a digital signal that your computer can understand.

Modulation: The process of varying the amplitude, frequency, or phase of a carrier or signal in telephone, radio, or television.

Multicoupler: A device used to connect a multitude of receivers to a single antenna.

Noise: An unwanted signal or disturbance (e.g., static) in a radio communications system.

Omnidirectional: Receiving or sending radio waves equally well in all directions.

Oscillator: A device for producing alternating current, specifically for producing radio frequencies.

Polarization: The action or process of affecting radiation so that the vibrations of the wave assume a definite form.

Propagation: The action of traveling and spreading through space, in reference to wave energy.

Receiver: The portion of a radio device that converts the radio waves into audible signals.

Refarming: An administrative process being conducted by the FCC to reduce channel bandwidths and, as a result, promote spectrum efficiency.

Repeater: A transmitter and a receiver operating on different frequencies and often connected to a common antenna.

Skip: The phenomenon by which a radio wave reflects from the ionosphere during the height of the sunspot cycle, often resulting in severe interference problems.

Spectrum: The region of the electromagnetic spectrum in which radio transmission and detection techniques may be used.

Spectrum efficiency: The ability to optimize the amount of information sent through a given amount of bandwidth.

Steering Committee: A group of usually high-level officials charged with setting policy for a project.

Transmitter: The portion of a radio device that sends out the radio signal.

Vocoder: Abbreviation for voice coder, a circuit that samples a voice frequency and then changes the sampled information into binary digits to modulate the carrier.

Wave: A disturbance or variation that transfers energy progressively from point to point in a medium and that may take the form of a variation in electric or magnetic intensity or electric potential.

Wavelength: The distance in the progression of a wave from any one point to the next point of corresponding phase.

Acronyms

AASHTO	American Association of State Highway Transportation Officials
ACSB	Amplitude Compandered Single Sideband
AM	Amplitude Modulation
AMPS	Advanced Mobile Phone System
APCO	Association of Public-Safety Communications Officials, International
BJA	Bureau of Justice Assistance
BJS	Bureau of Justice Statistics
CDMA	Code Division Multiple Access
CDPD	Cellular Digital Packet Data
CFR	Code of Federal Regulations
COPS	Community Oriented Policing Services
COTS	Common Off-the-Shelf Software
DoD	Department of Defense
DOJ	Department of Justice
DOT	Department of Transportation
EHF	Extremely High Frequency
EMS	Emergency Medical Service
ERP	Effective Radiated Power
ESMR	Enhanced Specialized Mobile Radio
FAA	Federal Aviation Administration
FBI	Federal Bureau of Investigation
FCC	Federal Communications Commission
FCCA	Forestry Conservation Communication Association
FDMA	Frequency Division Multiple Access
FEMA	Federal Emergency Management Agency
FM	Frequency Modulation
FSK	Frequency Shift Keying
GEO	Geosynchronous Earth Orbit
GHz	Gigahertz (1 billion cycles per second)
GPS	Global Positioning System
GSA	General Services Administration
HALE	High Altitude Long Endurance
HF	High Frequency
Hz	Hertz (cycles per second)
IGA	Intergovernmental Agreement
IM	Intermodulation
IMSA	International Municipal Signal Association
JPA	Joint Powers Authority
KHz	Kilohertz (1,000 cycles per second)

LCRA	Lower Colorado River Authority
LEAA	Law Enforcement Assistance Administration
LEO	Low Earth Orbit
LLEBG	Local Law Enforcement Block Grants
LOS	Line of Sight
MEO	Medium Earth Orbit
MHz	Megahertz (1 million cycles per second)
MIU	Mobile Imaging Unit
MTSO	Mobile Telephone Switching Office
NAMPS	Narrowband Advanced Mobile Phone System
NASTD	National Association of State Telecommunications Directors
NCIC	National Crime Information Center
NCJRS	National Criminal Justice Reference Service
NCS	National Communications Systems
NENA	National Emergency Number Association
NIJ	National Institute of Justice
NLECTC	National Law Enforcement and Corrections Technology Center
NTIA	National Telecommunications and Information Administration
OET	Office of Engineering and Technology
OJJDP	Office of Juvenile Justice and Delinquency Prevention
OJP	Office of Justice Programs
PBX	Private Branch Exchange
PCS	Personal Communications System
PLMRS	Private Land Mobile Radio Services
POCSAG	Post Office Standardization Advisory Group
PSCC	Public Safety Coordinating Council
PSTN	Public Switched Telephone Network
PSWN	Public Safety Wireless Network
RF	Radio Frequency
RFI	Request for Information
RFP	Request for Proposals
RFQ	Request for Quotation
SHF	Super High Frequency
SIS	State Identification Systems
SMR	Specialized Mobile Radio
TCP/IP	Transmission Control Protocol/Internet Protocol
TDMA	Time Division Multiple Access
TETRA	TErrestrial TRunked RAdio
TIIAP	Telecommunications and Information Infrastructure Assistance Program
TOP	Technology Opportunities Program (formerly TIIAP)
UART	Universal Receiver/Transmitter
UHF	Ultra High Frequency
VHF	Very High Frequency

APPENDIXES

Appendix A
State Agencies Administering Byrne Program Grants

ALABAMA
Office of the Governor
334–242–7100

ALASKA
Alaska State Troopers
907–269–5082

AMERICAN SAMOA
Criminal Justice Planning Agency
011–684–633–5221

ARIZONA
Criminal Justice Commission
602–230–0252

ARKANSAS
Sentencing Commission
501–682–5018

CALIFORNIA
Office of Criminal Justice Planning
916–324–9163

COLORADO
Department of Public Safety
303–239–4400

CONNECTICUT
Office of Policy and Management
860–418–6416

DELAWARE
Criminal Justice Council
302–577–5030

DISTRICT OF COLUMBIA
Office of Grants Management and Development
202–727–6537

FLORIDA
Department of Law Enforcement
850–410–7001

GEORGIA
Criminal Justice Coordinating Council
404–559–4949

GUAM
Governor's Office
011–671–472–4201

HAWAII
Office of the Attorney General
808–586–1151

IDAHO
Department of Law Enforcement
208–884–7040

ILLINOIS
Criminal Justice Information Authority
312–793–8550

INDIANA
Criminal Justice Institute
317–232–1230

IOWA
Department of Public Safety
515–281–3211

KANSAS
Criminal Justice Coordinating Council
913–296–0926

KENTUCKY
Justice Cabinet
502–564–7554

LOUISIANA
Commission on Law Enforcement
225–925–4430

MAINE
Department of Public Safety
207–287–3619

MARYLAND
Governor's Office of Crime Control and Prevention
410–321–3521

MASSACHUSETTS
Executive Office of Public Safety
617–727–7775

MICHIGAN
Michigan State Police
517–336–6158

MINNESOTA
Office of Drug Policy and Violence Prevention
612–296–0922

MISSISSIPPI
Division of Public Safety Planning
601–359–7880

MISSOURI
Department of Public Safety
573–751–4905

MONTANA
Department of Justice
406–444–6194

NEBRASKA
Commission on Law Enforcement and Criminal Justice
402–471–2194

NEVADA
Department of Motor Vehicles and Public Safety
775–684–8077

NEW HAMPSHIRE
Office of the Governor
603–271–2121

NEW JERSEY
Department of Law and Public Safety
609–292–9660

NEW MEXICO
Department of Public Safety
505–827–9115

NEW YORK
Division of Criminal Justice Services
518–457–8462

NORTH CAROLINA
CJIN
919–719–6070

NORTH DAKOTA
Information Services Division
701–328–3190

NORTHERN MARIANA ISLANDS
Criminal Justice Planning Agency
670–664–4550

OHIO
Governor’s Office of Criminal Justice Services
614–466–0286

OKLAHOMA
District Attorneys Training and Coordinating Council
405–557–6707

OREGON
Department of State Police
503–378–3725

PENNSYLVANIA
Commission on Crime and Delinquency
717–787–8559, ext. 3064

PUERTO RICO
Department of Justice
787–729–2141

RHODE ISLAND
Governor’s Justice Commission
401–422–4493

SOUTH CAROLINA
Law Enforcement Division
803–896–7138

SOUTH DAKOTA
Office of the Governor
605–773–3661

TENNESSEE
Office of Criminal Justice Programs
615–741–8277

TEXAS
Office of the Governor
512–463–1919

UTAH
Commission on Criminal and Juvenile Justice
801–538–1056

VERMONT
Department of Public Safety
802–244–8718

VIRGINIA
Department of Criminal Justice Services
804–786–8718

VIRGIN ISLANDS
Law Enforcement Planning Commission
340–774–6400

WASHINGTON
Office of Financial Management
360–920–0528

WEST VIRGINIA
Office of Criminal Justice and Highway Safety
304–558–8814, ext. 215

WISCONSIN
Office of Justice Assistance
608–266–7282

WYOMING
Attorney General’s Office
307–777–5406

Appendix B
NTIA State Single Point-of-Contact List

ALABAMA
No State SPOC office

ALASKA
No State SPOC office

AMERICAN SAMOA
No State SPOC office

ARIZONA
Arizona State Clearinghouse
602–280–1315

ARKANSAS
State Clearinghouse
501–682–1074

CALIFORNIA
Office of Planning and Research
916–445–0613

COLORADO
No State SPOC office

CONNECTICUT
No State SPOC office

DELAWARE
Executive Department
302–739–3323

DISTRICT OF COLUMBIA
Office of Grants Management and Development
202–727–1705

FLORIDA
Florida State Clearinghouse
904–922–5438

GEORGIA
Georgia State Clearinghouse
404–656–3855

GUAM
Bureau of Budget and Management Research
011–671–472–2285

HAWAII
No State SPOC office

IDAHO
No State SPOC office

ILLINOIS
Department of Commerce and Community Affairs
312–814–6028

INDIANA
No State SPOC office

IOWA
Division of Community and Rural Development
515–242–4719

KANSAS
No State SPOC office

KENTUCKY
Department for Local Government
502–573–2382

LOUISIANA
No State SPOC office

MAINE
State Planning Office
207–287–3261

MARYLAND
Office of Planning
410–767–4490

MASSACHUSETTS
No State SPOC office

MICHIGAN
Southeast Michigan Council of Governments
313–961–4266

MINNESOTA
No State SPOC office

MISSISSIPPI
Department of Finance and Administration
601–359–6762

MISSOURI
Federal Assistance Clearinghouse
573–751–4834

MONTANA
No State SPOC office

NEBRASKA
No State SPOC office

NEVADA
Department of Administration
775–684–0209

NEW HAMPSHIRE
Office of State Planning
603–271–2155

NEW JERSEY
No State SPOC office

NEW MEXICO
Local Government Division
505–827–4370

NEW YORK
No State SPOC office

NORTH CAROLINA
Department of Administration
919–807–2323

NORTH DAKOTA
Office of Community Services
701–328–2094

NORTHERN MARIANA ISLANDS
Office of Management and Budget
670–664–2289

OHIO
No State SPOC office

OKLAHOMA
No State SPOC office

OREGON
No State SPOC office

PENNSYLVANIA
No State SPOC office

PUERTO RICO
Federal Proposals Review Office
809–727–4444

RHODE ISLAND
Department of Administration
401–222–2093

SOUTH CAROLINA
Office of State Budget
803–734–0494

SOUTH DAKOTA
No State SPOC office

TENNESSEE
No State SPOC office

TEXAS
Office of Budget and Planning
512–305–9415

UTAH
State Clearinghouse
801–538–1535

VERMONT
No State SPOC office

VIRGINIA
No State SPOC office

VIRGIN ISLANDS
Office of Management and Budget
340–774–0750

WASHINGTON
No State SPOC office

WEST VIRGINIA
Development Office
304–558–4010

WISCONSIN
State/Federal Relations
608–266–0267

WYOMING
Department of Administration and Information
307–777–5492

Appendix C
APCO Local Frequency Advisers
(Revised July 2000)

State/ Primary/ Alternate	Adviser Information		Phone Number
Alabama/P	John F. Wyckoff		334–666–2682 (V)
Mississippi/P	5800 Hanging Moss Court	Call First:	334–666–2682 (F)
	Mobile, AL 36609	E-mail:	jwyckoff@zebra.net
Alaska/P	Patrick Buller		425–649–4654 (V)
Washington/West/P	Washington State Patrol		425–957–2364 (F)
	Electronic Services Section	E-mail:	Pbuller@wsp.wa.gov
	2803 156th Avenue SE		
	Bellevue, WA 98007–6599		
Arizona/P	Raymond P. Bass		520–747–8903 (V)
	1361 South Edlin Avenue		520–790–7394 (F)
	Tucson, AZ 85711–6033	E-mail:	BassR@worldnet.att.net
Arkansas/P	Charles D. Brown		501–618–8717 (V)
	Arkansas State Police		501–618–8710 (F)
	Electronics Shop		(Make sure fax cover
	1 State Police Plaza		sheet displays full name
	Little Rock, AR 72209		and “Electronics Shop.”)
Home:	8419 Baseline Road	Home:	501–833–3881
	Little Rock, AR 72209	E-mail:	brown@aristotl.net
California/North/P	Art McDole		831–442–9981 (V)
	333 Tapadero Street		831–449–1776 (F)
	Salinas, CA 93906	E-mail:	artmcdole@salinas.net
California/North/Co-P	Preston Thomson		916–657–9264 (V)
	DGS State of CA Telecom Division		916–657–9233 (F)
	601 Sequoia Pacific Boulevard	Home:	916–797–1046 (V)
	Sacramento, CA 95814	E-mail:	pthomson@telecom.dgs.ca.gov

State/ Primary/ Alternate	Adviser Information		Phone Number
California/South/Co-P	Gary David Gray		714–704–7911 (V)
	Orange County Communications		714–704–7902 (F)
	840 North Eckhoff Street, Suite 104		
	Orange, CA 92868–1021	E-mail:	gdgray@OCCOMM.CO.ORANGE.CA.US
California/South/Co-P	David G. Buchanan		909–387–3337 (V)
	777 East Rialto Avenue		909–387–8859 (F)
	San Bernardino, CA 92415–0740	E-mail:	david_buchanan@eee.org
Colorado/P	Emery Reynolds		303–795–4910 (V)
	Arapahoe County Sheriff Comm.		303–795–7684 (F)
	5002 South Newton Street	E-mail:	emreynolds@aol.com
	Littleton, CO 80123–1712		
Connecticut/P	Jerry Zarwanski		860–685–8157 (V)
	State of Connecticut		860–685–8364 (F)
	DPS Office of Statewide Emerg. Telecomm.		
	POB 2794	E-mail:	zarwanskij@worldnet.att.net
	Middletown, CT 06457–9294		
UPS/Overnight:	1111 Country Club Road		
	Middletown, CT 06457–9294		
Delaware/P	Richard R. Reynolds		302–739–9648 (V)
	State of Delaware		302–739–9642 (F)
	Office of Telecommunications Mgt.	Pager:	302–247–0120
	801 Silver Lake Boulevard	Mobile:	302–242–5398
	Dover, DE 19904–2460	E-mail:	rrr@state.de.us
Florida/North/P	Lynn Pettingill		407–703–1756 (V)
	City of Apopka	Home:	407–703–1761 (F)
	P.O. Box 1229	E-mail:	lpettingill@apopke.net
	Apopka, FL 32704–1229		
Florida/South/P	John Daly	Work:	941–774–8794(V)
	6823 Darby Court		941–774–8811 (F)
	Naples, FL 34104	Home:	941–455–1486 (V)
		Pager:	941–982–0638
Georgia/P	Wray Hall		404–656–2042 (V)
	State of Georgia DOAS/ITS		404–657–0320 (F)
	200 Piedmont Avenue, 1402 W	E-mail:	whall@doas.state.ga.us
	Atlanta, GA 30334–9010	E-mail	wrayhall@compuserve.com

State/ Primary/ Alternate	**Adviser Information**		**Phone Number**
Guam/P	Melvin Morris		808–586–1920 (V)
Hawaii/P	Info. & Comm. Services Div.		808–586–1922 (F)
	POB 119	E-mail:	morrism@worldnet.att.net
	Honolulu, HI 96810–0119		
UPS/Overnight:	1151 Punchbowl Street, Room B10		
	Honolulu, HI 96813		
Idaho/P	Stanley Passey		208–585–2386 (V)
	1226 New York Street		
	Middleton, ID 83644		
Illinois/North/P	William J. Carter		312–746–9252 (V)
	Chicago Police Department		312–746–9202 (F)
	Office of Emergency Comm.	E-mail:	bcfire911@aol.com
	1411 West Madison		
	Chicago, IL 60607		
Illinois/South/P	Thomas J. Ward, Jr.		217–782–5742 (V)
	531 Sangamon Avenue		217–524–4396 (F)
	Springfield, IL 62702	E-mail:	wardt@worldnet.att.net
Indiana/P	H. Anthony Stantz		317–233–9026 (V)
	Indiana State Police		317–233–6059 (F)
	100 North Senate Avenue, Room N301		
	Indianapolis, IN 46204–2259	E-mail:	astantz@isp.state.in.us
Iowa/P	Richard Hester		712–769–2395 (V)
	Iowa State Patrol Communications		712–769–2475 (F)
	56911 White Pole Road		
	Lewis, IA 51554		
Kansas/P	Leon Gray		785–536–4361 (V)
	Bureau of EMS		785–536–4526 (F)
	2303 South Cunningham Road		
	Salina, KS 67401–9042		
Kentucky/P	In House		

State/ Primary/ Alternate	**Adviser Information**		**Phone Number**
Louisiana/P	Bill Vincent		318–291–5060 (V)
	POB 82236		318–291–5080 (F)
	Lafayette, LA 70598	E-mail:	billvincent@worldnet.att.net
UPS/Overnight:	800 South Buchanan Street		
	Parish Courthouse Basement		
	Lafayette, LA 70501–3286		
Maine/P	Mark Poole		207–624–7091 (V)
	Maine State Police		207–624–7088 (F)
	36 Hospital Street	E-mail:	mark.w.poole@state.me.us
	Augusta, ME 04333–0042		
Maryland/P	Sgt. Stanley A. Sines		202–727–6752 (V)
	Metropolitan Police Department		202–727–6758 (F)
	15808 Wayne Avenue	Pager:	302–247–0120
	Laurel, MD 20707–3256	E-mail:	rrr@state.de.us
Massachusetts/P	James Warakois		617–343–4214 (V)
Rhode Island/P	Boston Police Department		617–343–5343 (F)
	2626 Centre Street	E-mail:	koisj@ziplink.net
	West Roxbury, MA 02132		
Michigan/P	William Folske		734–741–1346 (V)
	1235 South Maple, #102		734–741–1846 (F)
	Ann Arbor, MI 48103	E-mail:	wfolske@worldnet.att.net
Minnesota/Co-P	Roger Kochevar		651–296–7419 (V)
(PP & all 800 MHz)	Minnesota Department of Transportation		651–297–5735 (F)
	Electronic Communications		
	161 St. Anthony, Suite 900, Kelly Annex		
	St. Paul, MN 55103		
Minnesota/Co-P	Mike Hogan		651–296–7421(V)
(PL non-800 MHz)	Minnesota Department of Transportation		651–297–5735 (F)
	Electronic Communications		
	161 St. Anthony, Suite 900, Kelly Annex		
	St. Paul, MN 55103		
Mississippi/P	John F. Wyckoff		334–666–2682 (V)
Alabama/P	5800 Hanging Moss Court	Call First:	334–666–2682 (F)
	Mobile, AL 36609	E-mail:	jwyckoff@zebra.net

State/ Primary/ Alternate	**Adviser Information**		**Phone Number**
Missouri/P	Steve Devine		573–526–6105 (V)
	Missouri State Highway Patrol		573–526–1112 (F)
	1510 East Elm Street	E-mail:	sdevine@mail.state.mo.us
	POB 568		
	Jefferson City, MO 65101		
Montana/P	Homer Young		406–841–3958 (V)
	Montana Disaster Emergency Service Division		406–841–3965 (F)
	POB 4789	E-mail:	Hyoung@state.mt.us
	Helena, MT 59604		
UPS/Overnight:	1100 North Main Street		
	Helena, MT 59601		
Nebraska/P	Mike Jeffres		402–471–3719 (V)
	State of Nebraska Div. of Communications		402–471–3339 (F)
	Executive Building	E-mail:	mjeffres@doc.state.ne.us
	521 South 14th Street, Suite 300		
	Lincoln, NE 68508–2707		
Nevada/P	Mel Pennington		775–688–2528 (V)
	Nevada Highway Patrol	Call First:	775–688–3339 (F)
	557 Hammill Lane	E-mail:	mpenning@govmail.state.nv.us
	Reno, NV 89512		
New Hampshire/P	Jim Kowalik		603–271–2421 (V)
	New Hampshire Department of Safety		603–271–6629 (F)
	State Police Comm. Maint.	E-mail:	kowalik@worldnet.att.net
	10 Hazen Drive		
	Concord, NH 03305		
New Jersey/P	In House (George Johnson)		
New Mexico/P	James (Jim) Gordon		505–461–0499 (V)
	710 South Adams		505–461–0492 (F)
	Tucumcari, NM 88401	E-mail:	james.gordon@state.nm.us
New York/North/P	Gary E. Perkins		716–528–2246 (V)
	911 Technical Services		716–528–2265 (F)
	Office of Emergency Communications	E-mail:	perkinsg@worldnet.att.net
	321 West Main Street		
	Rochester, NY 14608–1902		
UPS/Overnight:	321 West Main Street		
	Rochester, NY 14608–1902		

State/ Primary/ Alternate	Adviser Information		Phone Number
New York/South/P	Vincent R. Stile		516–852–6431 (V)
	Suffolk County Police		516–852–6418 (F)
	Command 5340	E-mail:	stilevin@nais.com
	30 Yaphank Avenue		
	Yaphank, NY 11980–9705		
New York/South/P	Mary Tornetta		516–852–6432 (V)
	Suffolk County Police		516–852–6418 (F)
	Command 5340		
	30 Yaphank Avenue		
	Yaphank, NY 11980–9705		
North Carolina/P	Dyke Hostettler		919–662–4440 (V)
	NC State Highway Patrol IMU Unit		919–662–4444 (F)
	3318 Garner Road, IMU Bldg. 2	E-mail:	dhostettler@ncshp.org
	Raleigh, NC 27610		
Home:	41 Hagwood Road		
	Zebulon NC 27597		
North Dakota/P	Lyle V. Gallagher		701–328–8150 (V)
	State Radio Communications		701–328–8155 (F)
	Box 5511 Fraine Barracks Road	E-mail:	lgallagh@pioneer.state.nd.us
	Bismarck, ND 58502–5511		
Ohio/P	Donald G. Flahan		216–524–7417 (V)
	857 East Dartmoor		216–524–6535 (F)
	Seven Hills, OH 44131		
Oklahoma/P	Gene Thaxton		405–425–2231 (V)
	Oklahoma Public Safety Department		405–425–2029 (F)
	POB 11415	E-mail:	gthaxton@dps.state.ok.us
	Oklahoma City, OK 73136		
	(or) 3600 M. L. King (zip-73111)		
Oregon/P	Joe Kuran		503–690–4911, ext. 267 (V)
	Washington City Consol. Comm. Agency		503–531–0186 (F)
	17911 N.W. Evergreen Pkwy.	E-mail:	jkuran@wccca.com
	Beaverton, OR 97006		
Pennsylvania/P	George Johnson (In House)		

State/ Primary/ Alternate	Adviser Information		Phone Number
Puerto Rico/P	Angel M. Montes		787–720–3145 (V)
Virgin Islands/P	GG-15B Magnolia Street		787–720–3145 (F)
	Borinquen Gdns.		
	San Juan, PR 00926–0000		
Rhode Island/P	James Warakois		617–343–4214 (V)
Massachusetts/P	Boston Police Department		617–343–5343 (F)
	2626 Centre Street	E-mail:	koisj@ziplink.net
	West Roxbury, MA 02132		
South Carolina/P	Buddy Jordan		803–896–0443 (V)
	4430 Broad River Road		803–896–0088 (F)
	Columbia, SC 29201	E-mail:	jordanb@oir.state.sc.us
South Dakota/P	Todd Dravland		605–773–4635 (V)
	State Radio Communications		605–773–4629 (F)
	500 East Capitol Avenue		
	Pierre, SD 57501		
Tennessee/P	John Johnson		615–741–3826 (V)
	4130 Azalea Court		615–741–6027 (F)
	Murfreesboro, TN 37128	E-mail:	jjohnson@hotcom.net
Texas	Ken Yoder		512–424–2104 (V)
	Texas Department of Public Safety	512–424–2899 (F)	
	Box 4087	E-mail:	kcyoder@gte.net
	5805 North Lamar Boulevard		
	Austin, TX 78773–0254		
Utah/P	Robert (Bob) T. Marz		801–479–7710 (V)
	569 East 43rd Street		801–479–5267 (F)
	South Ogden, UT 84403–2852	E-mail:	marzb@worldnet.att.net
Vermont/P	Terry M. LaValley		802–244–8786 (V)
	Vermont Department of Public Safety		802–244–1106 (F)
	Division of State Police		
	103 South Main Street		
	Waterbury, VT 05671		

State/ Primary/ Alternate	Adviser Information		Phone Number
Virginia/P	David R. Warner		804–674–2208 (V)
	Virginia State Police		804–674–2602 (F)
	POB 27472	E-mail:	dwarner404@aol.com
	Richmond, VA 23261–7472		
UPS/Overnight:	7700 Midilothian Tpk.		
	Richmond, VA 23235		
Virgin Islands/P	Angel M. Montes		787–720–3145 (V)
Puerto Rico/P	GG-15B Magnolia Street		787–720–3145 (F)
	Borinquen Gdns.		
	San Juan, PR 00926–0000		
Washington/East/P	Wayne Wantland		509–575–6048 (V)
	8809 Alpine Court		509–576–6361 (F)
	Yakima, WA 98908		
Washington/West/P	Patrick E. Buller		425–649–4654 (V)
	Washington State Patrol		425–957–2364 (F)
	2803 156th S.E.		
	Bellevue, WA 98007		
Washington DC/P	Richard A. Reynolds		302–739–9648 (V)
	State of Delaware		302–739–9642 (F)
	Office of Telecomm. Mgt.	E-mail:	rrr@state.de.us
	801 Silver Lake Boulevard		
	Dover, DE 19904–2460		
West Virginia/P	Frederick B. Smart		800–624–0742 (V)
	Harrison Cty. Bureau of Emergency Services		304–623–6558 (F)
	420 Buckhannon Pike		
	Nutter Fort, WV 26301–4343	E-mail:	FSmart@northnap.citynet.net
Wisconsin/P	Carl R. Guse		608–266–2497 (V)
	Wisconsin State Patrol		608–267–4495 (F)
	POB 7912	E-mail:	carl.guse@dot.state.wi.us
UPS/Overnight:	4802 Sheboygan Avenue, Room 551		
	Madison, WI 53707–7912		
Wyoming/P	Bill Smith		307–777–4440 (V)
	Wyoming Department of Transportation		307–777–4764 (F)
	Telecommunications Program	E-mail:	bsmith1@missc.state.wy.us
	POB 1708		
	Cheyenne, WY 82003–1708		
UPS/Overnight:	5300 Bishop		
	Cheyenne, WY 82009		

Appendix D
Resources

Agency/Subagency	Web Address	Telephone
Federal Agencies/Programs:		
DOJ	www.usdoj.gov	800–421–6770
BJA	www.ojp.usdoj.gov/bja	202–307–0703
COPS	www.cops.usdoj.gov	800–421–6770
NCJRS	www.ncjrs.org	800–851–3420
NIJ	www.ojp.usdoj.gov/nij	202–307–2942
FAA	www.faa.gov	800–322–7873
FBI	www.fbi.gov	202–324–3000
CALEA	www.fbi.gov/programs/calea/calea.htm	800–551–0336
NCIC	www.fbi.gov/library/2000/pdinfo.htm	304–625–2730
FCC	www.fcc.gov	888–225–5322
GPO (for printed FCC rules)	www.gpo.gov	
NLECTC	www.nlectc.org	800–248–2742
NLECTC–RM	www.nlectc.org/nlectcrm	800–416–8086
NTIA	www.ntia.doc.gov	202–482–5802
TOP	www.ntia.doc.gov/otiahome/top	202–482–2048
PSWN	www.pswn.gov	800–565–7796
Membership Organizations:		
AASHTO	www.aashto.org	202–624–5800
APCO	www.apco911.org	888–272–6911
FCCA	http://home.flash.net/~malamber/FCCA/FCCAHome.html	202–624–5416

IMSA	www.imsasafety.org	800–723–4672
NENA	www.nena9-1-1.org	800–332–3911