THE AEROSPACE CORPORATION

Final Report

EXTERNAL ALARM TRANSMISSION MEDIA EVALUATION

By: S. SCALA, G. C. BYRNE, T. KOVATTANA, D. LOHR, and F. A. SCHOOLEY

Prepared for:

THE AEROSPACE CORPORATION
P.O. BOX 92957
LOS ANGELES, CALIFORNIA 90009

P.O. 44365-V under
CONTRACT J-LEAA-025-73

STANFORD RESEARCH INSTITUTE
Menlo Park, California 94025 · U.S.A.

SRI

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Approved by:

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Engineering Systems Division

ABSTRACT

This study evaluated and compared media that may be suitable through the 1980s for transmission of alarm signals, particularly as applied to future low-cost residential or small business burglar alarms.

The principal transmission media considered were cross-town power lines, telephone, cable television, and radio. A major part of the study consisted of gathering data from relevant sources. The evaluation parameters included cost, availability, reliability, and regulatory and policy constraints.

The results indicate that telephone circuits using multiport bridges and CATV, if available, may represent optimum solutions for the commercial grade of alarm service; telephone auto-dialers and CATV represent the low-cost solutions. Currently available radio systems are too costly; significant reduction of equipment costs and improvements in reliability are necessary to make radio cost competitive with telephone or CATV media. Cross-town power lines are not expected to be available or desirable for alarm signaling because of the policies of the utilities and the nature of the network.

Recommendations are made for developing a set of requirements for low cost auto-dialer alarms, and for further investigation of potentially low-cost radio communication systems.

PREFACE

The SRI study team organized to perform the analysis of Alarm Transmission Media reflected several disciplines and was drawn from two of SRI's eight divisions:

- Engineering Systems Division
  - Systems Development Department
  - Systems Planning Department
  - Center for Analysis of Public Services
- Economics Division

  Communication Industries Department.

Specific contributions of individual team members were as follows:

Mr. G. C. Byrne	Systems Development Department	Program manager and principal contributor in the area of resistance to tampering
Mr. T. Dayharsh	Center for Analysis of Public Services	Principal contributor in the area of FCC rules and regulations
Dr. T. Kovattana	Systems Development Department	Principal contributor in the area of the radio frequency (RF) medium
Mr. D. Lohr	Communication Industries Department	Principal contributor in the areas of telephone and CATV media
Mr. S. Scala	Systems Development Department	Overall coordinator of the report and principal contributor in the area of cross-town power lines medium
Mr. F. A. Schooley	Systems Planning Department	Principal contributor in the area of cost analysis

EXECUTIVE SUMMARY

EXTERNAL ALARM TRANSMISSION MEDIA EVALUATION

A. Study Objectives

This report is a summary of the results of a comparative evaluation of alternate media for transmission of burglar, holdup, and other emergency alarm signals from instrumented premises to a response agency. Detailed, supporting documentation of the results summarized in this report are contained in a separate Data Package.

This study was undertaken because of the decreasing availability of telephone dc wire pairs, which thus far have been the mainstay of burglar alarm service, and their gradual replacement by carrier (multiplex) channels. The transmission media that were evaluated were (1) alternative ways of using telephone facilities, (2) cable television (CATV), (3) radio (RF), and (4) cross-town power distribution lines. These media were evaluated in terms of cost, availability, reliability, and regulatory and policy constraints. Because the primary intended application of such media, as far as this study is concerned, is for low-cost residential and small-business alarm service, the cost characteristics of the competing media are of paramount importance. The final objective of this study was to develop recommendations for further technical effort needed in this area.

B. Promising Media

The study focused on two broad categories of alarm service: (1) the conventional, high-effectiveness, commercial service that may conform to the requirements of Underwriters Laboratories; (2) low-cost alarm service, such as may be adequate for residential/small-business applications,

but which does not necessarily meet the stringent requirements imposed on the conventional central station type of alarm system. Of the promising transmission media, those suitable for conventional, commercial alarm service include the dedicated telephone systems and CATV, if available; those suitable for low-cost alarm service include primarily the telephone auto-dialers, but also CATV, particularly if and when wide-spread implementation of various interactive services via CATV takes place.

A summary comparison of the costs of the candidate transmission media/systems is given in Section E, following the description of the media given below.

1. Telephone systems. These dedicated telephone systems utilize multiport bridges, which permit transmission of alarm signals over modern frequency-division-multiplex (FDM) telephone channels. In particular, a "closed window" bridge,* currently under development by American Telephone and Telegraph Corp. (AT&T), should offer a high degree of resistance to jamming of the network from any one port. A number of "open window" bridges currently on the market represent alternative solutions.

An interesting variation of the multiport bridge is the so-called "nodule" concept, in which multiple subscriber terminals are connected to each port; thus, the costs of the lease line between the subscriber terminal and the bridge are shared by as many as 10 subscribers, significantly reducing the overall cost per subscriber. However, this concept is practical only in the case of very high subscriber densities, in which case potential low cost per subscriber would make this concept attractive for low-cost alarm applications as well.

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*Available in the last quarter of 1976.

In the low-cost alarm service category, the digital telephone auto-dialer appears to offer the lowest-cost, universally available solution, at least for the near-term future, because the cost of the telephone line is already absorbed elsewhere. A large number of auto-dialers are currently on the market. Although some of these may already incorporate many of the features that are desirable for low-cost alarm signal transmission--such as periodic self-checking, and capability to free the line if otherwise in use under alarm conditions--a specific set of requirements for auto-dialers for this application needs to be developed.

Currently, telephone companies* require an interface device (coupler) between the ancillary equipment on a subscriber's premises and the telephone line for all auto-dialers, except those leased from the telephone company. The coupler is leased for an added monthly fee. If this requirement could be eliminated, a substantial reduction in the monthly cost of non-telco dialers would result.

2. Cable television (CATV). This medium represents another potentially cost/effective transmission alternative. Although it is doubtful that this medium will approach the same high degree of availability as telephone systems, current marketing forecasts indicate that in mid-1980s about 75 percent of all households in the United States will have access to CATV cable. Another important factor in utilizing this medium for alarm signal transmission is the projected implementation of two-way transmission capability over CATV cable for such interactive applications as pay-TV, educational, information, merchandising, computer, and others. When two-way transmission capability will have been implemented and its cost sunk, the addition of alarm service can be obtained at very moderate cost; in fact, in that case CATV represents potentially the lowest-cost

*Except, currently, in California.

long-term solution, for low-cost, as well as conventional alarm service. As in the case of the telephone auto-dialer, the low cost of CATV alarm transmission systems results from "piggybacking" alarm traffic onto a medium that has been developed and deployed for other applications.

The technology required to implement the interactive services via CATV is well developed. However, the resistance to tampering of the first-generation CATV alarm transmission systems is expected to be somewhat lower than that of the dedicated telephone alarm systems, such as the dc loop, direct wire, and the "closed window" multiport bridge.

Although current ruling by the Federal Communications Commission (FCC) requires that all CATV systems in the top 100 markets have two-way plug-in capability by 1977, the actual implementation of two-way transmission capability will depend on the economic viability of the interactive services.

C. Media Showing Limited Promise, or Otherwise Constrained

1. Radio systems. No definitive conclusion was reached regarding the potential cost/effectiveness of new (not yet designed) radio systems. Currently available radio systems are expensive and require much maintenance. This is particularly true if the transmitter power exceeds 3 W, in which case the cost of annual inspection as required by FCC is high. Thus, currently available RF systems cannot compete on the cost basis with the telephone and the CATV media.

Before a decision can be reached about the eventual cost-effectiveness of this medium, compared with those of the media discussed above, it is first necessary to determine whether radio alarm systems can be designed to operate reliably with transmitter power below the levels that require annual inspection, in accordance with FCC regulations. If the answer to this question is affirmative, it will be desirable to explore

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C. Media Showing Limited Promise, or Otherwise Constrained

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2. Cross-town power lines. Cross-town power lines will not be available for alarm signal transmission. This is because of a stated or implied policy of electric power utilities arising from (1) their apprehension that alarm signal transmission might interfere with or degrade the quality of the primary service, i.e., providing electricity to homes and businesses, (2) fear of increased regulation, and (3) lack of visible financial incentive. In addition, the adaptation of this medium to alarm signal transmission would be faced with difficult-to-overcome technical problems, the most important of which are (1) the inherently high noise levels, (2) severe signal attenuation across the power distribution system components, and (3) lack of single predictable signal paths across the complex, time-varying (switched) distribution networks.

D. Other (Unconventional) Media

A brief evaluation of such unconventional transmission media as lasers, microwave, and optic fibers disclosed that, while these media provide much higher data rate capabilities than the major transmission media under consideration, they cannot compete with them on a cost basis; also, some of them suffer from technical shortcomings for the alarm transmission application. The use of water lines (using pressure transducers) was also considered and found impractical.

E. Comparison of Transmission Costs

Table S-1 shows a comparison of the present and the projected future transmission media costs, on a monthly cost basis, for the principal

Table S-1

COMPARISON OF CURRENT AND PREDICTED FUTURE COSTS OF ALARM TRANSMISSION MEDIA/SYSTEMS

Medium/System			Monthly Costs per Subscriber (1975 dollars) Present	Future Near-Term	Future Long-Term
Telephone	Hard-wired systems	Current, dc loop (McCulloh)[1]	$ 4.19	$ 5.69[2]	$ 7.69[2]
		Direct wire	13.50	14.90	16.90
	Multiport bridge		9.51	11.05	13.12
	Multiport bridge with "nodule"[3]		Not available	5.38[3]	5.65[3]
	Leased telco dialer		8.12	8.12	8.12
	Non-telco dialer		12.43	12.43 (6.93)[4]	12.43 (6.93)[4]
Cable television			Not available	7.24[2,5]	4.28[2,6]
Radio			18.03	18.88	9.17[7]

[1]Presented for reference.

[2]If available.

[3]Requires high subscriber density (10 subscribers in proximity of one another share one lease line).

[4]Cost reduction if interface requirements (by telephone company) are eliminated.

[5]In addition to cost of TV service; cost of implementing two-way capability borne by alarm service subscribers.

[6]In addition to cost of TV service; cost of implementing two-way capability borne by other interactive services.

[7]Cost decrease predicated on achievement of improved reliability and elimination of the annual inspection requirement (by FCC), or reliable operation at low power levels (below FCC regulatory limit).

media/system categories that were evaluated. The specific assumptions and methodology used in deriving these costs are too complex to be presented in the Executive Summary; they can be found in Chapter 3, Section F of this report. The reader is cautioned against using these cost figures without a thorough understanding of the underlying assumptions; the cost data are presented here primarily to provide a basis for quick comparative--rather than absolute--evaluation of the costs of the candidate media/systems.

F. Recommendations for Further Development

In evaluating candidate transmission media/systems for alarm signaling applications to determine the most promising, SRI did not uncover any major gaps in technology or in other areas where intensive follow-on studies or further technical development under LEAA/Aerospace sponsorship would be expected to yield large payoffs. This is primarily because many of the media operators and media equipment developers have already undertaken and/or completed such needed development, e.g., the CATV equipment manufacturers, the "closed-window" multiport bridge undergoing development by AT&T through their Bell Telephone Laboratories subsidiary. Also, the use of some candidate media is economically constrained, and additional technological developments cannot be expected to expedite the future availability of the medium; this is clearly the case with CATV. Nevertheless, this study uncovered some secondary problem areas and technological gaps that warrant further exploration, and the resolution of which can be expected to decrease the above system costs and/or improve their reliability. Accordingly, the following recommendations for future work are made:

- A study should be undertaken to establish a set of requirements for telephone auto-dialers for low-cost, alarm signaling applications, which would include the required and

desirable features of auto-dialers for this application, determined on the basis of operational needs (including resistance to tampering) and cost. Also, the current requirement by telephone companies for the interface device for connecting non-telco auto-dialers to the telephone system should be reexamined. The results should be communicated to the state public utility commissions, particularly in those states where the requirement for such couplers is being disputed or is under litigation by the manufacturers of ancillary equipment and the telephone companies, in order to help resolve this issue.

- If it can be determined that reliable alarm signal transmission using radio can be accomplished with transmitter powers below the FCC regulation limit, it will be desirable to determine whether some new, ingenious implementation scheme may offer low equipment cost and improved reliability to the degree that would make this medium cost-competitive with telephone or CATV.
- Since the telephone companies are already engaged in development of multiport bridges for alarm signaling application, no additional external funding of this effort is needed.
- Since growth of the two-way CATV medium depends largely on the economic viability of the interactive services that have been proposed rather than on technology development or the regulatory environment, no specific recommendations regarding studying this medium can be made. The FCC should be informed that if widespread implementation of low-cost burglar alarm systems should take place, the two-way CATV medium will be a strong contender for this service.
- Further studies of the cross-town power lines as a potential medium for alarm signal transmission should be discontinued.

In addition, in the course of this study, the SRI researchers elicited spontaneous responses from various sources to the effect that portable burglar alarms that could be rented or leased and used on the premises while the family is away on vacation would find wide acceptance. The technical and the aesthetic requirements for such portable "vacation" alarms are quite different from those for permanent alarm installation and should be developed. Prototype hardware development is also desirable.

ACKNOWLEDGMENTS

The authors wish to acknowledge the assistance and cooperation of staff members of The Aerospace Corporation.

In addition, valuable assistance in the form of readily provided information was supplied by alarm operators (in particular, the Burns International Security Corporation), the police and fire departments in the jurisdictions selected as typical of U.S. population centers, cable television operators, electric utilities and telephone companies, and manufacturers of telephone, CATV, radio and alarm equipment.

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ILLUSTRATIONS

TABLES

CHAPTER 1. INTRODUCTION

The External Alarm Transmission Media Evaluation was a seven-month study conducted by Stanford Research Institute (SRI) under subcontract to The Aerospace Corporation as a part of that organization's Equipment Systems Improvement Program for the National Institute of Law Enforcement and Criminal Justice (NILECJ) of the Law Enforcement Assistance Administration (LEAA). The purpose of the Program is "to encourage research and development to improve and strengthen law enforcement." The purpose of the SRI study within this program was to conduct a comprehensive comparative evaluation of alternate transmission media for residential and small-business burglar alarms through the 1980s, and make recommendations for further developmental efforts.

To facilitate the distribution of the results of this study to a broad spectrum of interested organizations, which may include alarm companies, electric power utilities, telephone companies, cable television (CATV) system operators, state and local governments (including police and fire departments) and individuals, this report contains only a summary of the findings of this investigation, and uses a minimum of technical terminology. Detailed technical, cost, and technoeconomic analyses, which support the findings contained herein may be found in a supplementary Data Package. A limited number of copies of the Data Package were supplied by SRI to The Aerospace Corporation under this contract. Requests for specific memoranda or technical notes contained in the Data Package should be directed to Aerospace.

A. Background

The need for a low-cost, reliable, residential and small business alarm system has been documented in surveys conducted by private companies and local police departments and in studies carried out under the auspices of government agencies, such as LEAA.

Although a variety of security alarm systems are commercially available, most are directed toward protection of commercial or industrial properties and are custom designed and installed. The cost of these systems is too high for middle or lower income areas where surveys have shown that crime rates are highest. In addition, excessive false alarm rates reduce the effectiveness of an alarm network due to an inability or unwillingness of the response agent to respond to the alarm that has more than a 90 percent probability of being false.

Most existing alarm systems use conventional hard-wire telephone lines, although direct wiring or radio frequency (RF) techniques are also used. These methods have many limitations and may not be suitable for alarm data transmission in the low-cost, high-volume system envisione Therefore, new methods or new applications of existing methods must be considered. The comprehensive comparison of external transmission method resulting from this study should be of great value in making decisions in areas such as manufacturing, marketing, and private/government funding of research and development for a new generation of alarm systems.

B. Objectives

The purpose of the study was to conduct a qualitative and quantitative comparison of existing, proposed, and potentially feasible media for external transmission of security alarms between protected premises (residences and small business establishments) and a central alarm stati In particular, the objectives were to identify and rank media and system that are potentially economical and practical for large scale employment in low- and middle-income areas.

The study sought answers to the following questions:

- At present, which is the best choice for alarm transmission media through 1980?
- Which of the alarm transmission media require new or expanded development efforts?
- If only system modifications are introduced, what will be the most beneficial alarm transmission media through the 1980s?
- What factors, not previously considered, are of significance in the investigation and selection of alarm transmission media?

C. Scope

The total security alarm system is composed of four principal elements:

- Sensors.
- A protected premises with an integrated control system including processor.
- An external transmission medium that carries the alarm data between the residential processor and the central station.
- Central station with response function.

The scope of this study was limited to the external transmission media element of the total security system, including the interfaces with the premises control system processor and the central station (i.e., the receiving function).

The communication media that were evaluated in the program were the following:

- Cross-town power transmission lines as a medium for carrier-modulated data.
- Two-way or interactive cable TV (CATV) system.
- Expanded use of telephone company equipment.

- RF transmission of alarm data directly from a residence to a police dispatch car, a police station, or an alarm response company.
- Hybrid transmission system utilizing appropriate elements of the preceding transmission media (1 through 4).
- Other transmission media such as lasers, microwave, optic fibers, water lines, and strobe lights.

This study emphasized the real-word constraints, including the expected acceptability of potential solutions by the alarm industry, policies and attitudes of the media owners, projected media growth within the time span of interest, and regulatory constraints and their projected evolution. As the study progressed, it became obvious that such constraints surpassed in importance technological considerations; consequently, the emphasis of this investigation was adjusted accordingly.

D. Approach

Data gathering was an important part of this investigation. It included a literature survey, using, among others, the SRI data bank on related topics from previous investigations, data supplied by The Aerospace Corporation, and data from other sources. In addition, SRI undertook an extensive survey of various interested organizations, such as electric utilities, telephone companies, CATV operators, developers of remote reading systems for utility meters, alarm company operators, manufacturers of various types of communications equipment, police departments, and the Federal Communications Commission (FCC). This information gathering task continued throughout the study.

The system requirements for transmission of alarm signals may vary widely with such parameters as the total number of subscribers per central reporting station, population density, and the geographical extent of the area covered by the alarm system net. The relevant system requirements influenced by such parameters include the traffic rate and the average length of alarm communication links. Thus, different circumstances may require different approaches to alarm signal transmission. For this reason, SRI configured three separate conceptual urban/population "models" for use in the evaluation process. Each of these models corresponds to a different type of area that is to be protected by a central alarm system: urban, suburban, and an isolated small town surrounded by an agricultural area.*

The function of the urban/population models was to:

- Provide a broad conceptual frame of reference including a ready set of statistical and other reference data that characterize the area types in terms of parameters that are, or may be, significant to alarm signal transmission.
- Inject realistic conditions and constraints into the study.
- Uncover potential problem areas or special conditions that might not otherwise be apparent.

The study covered the following overlapping, principal areas:

- Definition of general alarm transmission system parameters.
- Investigation of feasible alarm transmission media.
- Determination of the state-of-the-art of external alarm transmission capabilities.
- Compilation of a comparative evaluation or trade-off study of the various media with parameters such as cost, reliability, availability, and compatibility with alarm system and central response modes.
- Formulation of conclusions and recommendations concerning the selection of an alarm transmission medium now and through the 1980s, and areas in which specific development efforts are required for more effective alarm transmission systems.

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*The corresponding exemplar areas used in this study are: (a) San Francisco, CA--Western Addition division, (b) Mountain View, CA, and (c) Gilroy, CA.

These efforts were conducted essentially in parallel, although emphasis on each effort varied during the study. Figure 1 shows the functional flow chart of the program, which illustrates the interactions between the major elements and areas of the study.

Each of the potential or proposed alarm signal transmission media was evaluated in conjunction with each of the three urban/population area models and compared with the baseline case in terms of their cost, effectiveness, and other system parameters. The baseline case (i.e., The McCulloh loop) corresponded to the current U.S. implementation and technology of alarm signal transmission via leased telephone lines. Since leased telephone lines are the principal medium for transmission of alarm signals at present, this medium represents a sound foundation for the comparative analysis.

For each promising transmission system concept the relevant technical parameters were defined, technical trade-off analyses were performed, as needed, and overall systems costs were computed. The candidate systems were then compared and ranked in terms of cost, technological availability, expected reliability, compatibility with existing systems, technological limitations, resistance to tampering, expansion (growth) potential, projected media coverage, and regulatory, policy, and economic constraints.

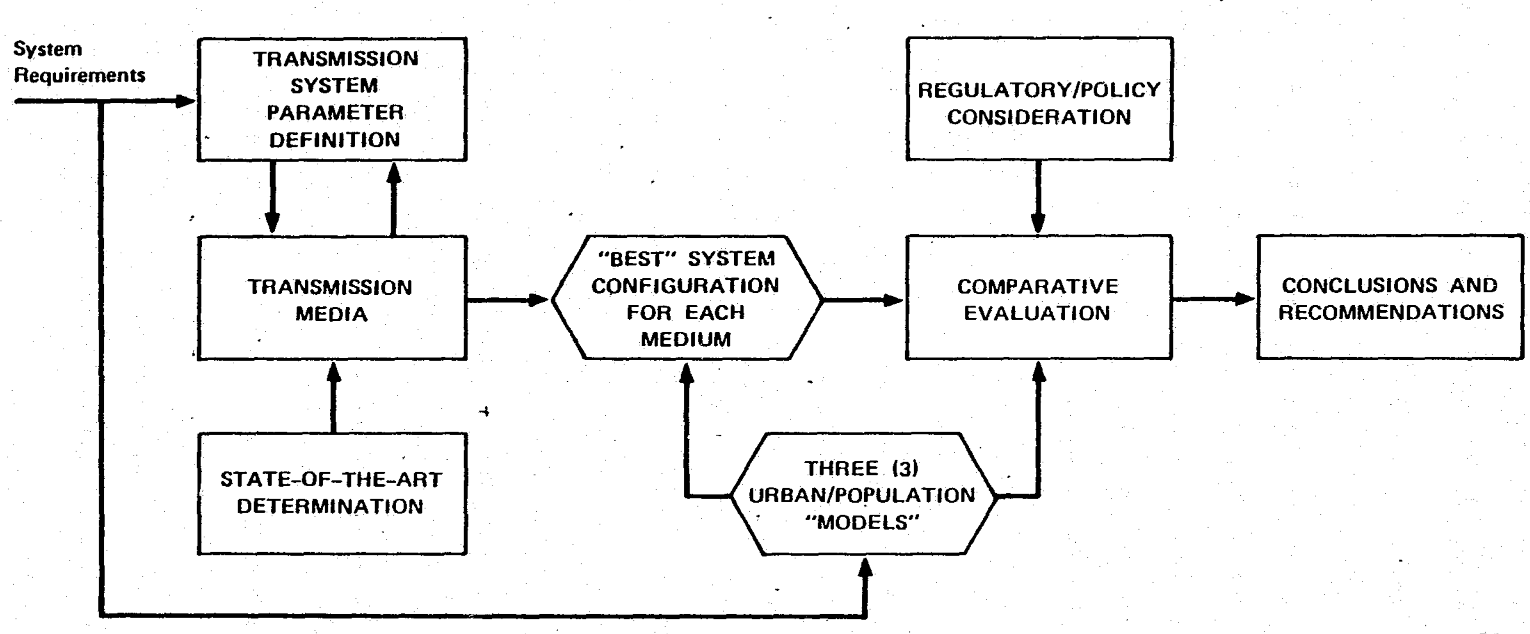

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FIGURE 1 STUDY FLOW CHART

CHAPTER 2. TRANSMISSION MEDIA

A. Background

At present, conventional hard-wire telephone service is used as the primary means for the transmission of alarm data from the subscribers to the alarm service company or police station. These are dedicated direct copper-wire paths that are monitored or supervised at the central station and are generally used to service from 1 to 45* subscribers per wire pair, depending on the type of equipment the alarm company is using.

Dedicated telephone rental costs are increasing very rapidly, and telephone companies have already given warning that additional dedicated, hard-wire lines will not be provided across the boundaries of central office service areas because such lines are being replaced by voice/data grade communication channels in the modernization of telephone plant equipment; these new channels incorporate RF carrier techniques and can only transmit ac or tone signals. Future availability of dc wire pairs is in question even within central office service areas. Some automatic telephone dialer systems are currently available but at present their cost and reliability requirements, for alarm signaling, are ill-defined.

As a means to overcome these problems, new methods and improvements of existing techniques that may be applicable for communication of alarm data from a residence (or a retail business establishment) to a response agency were investigated. Some of these methods are currently under development; others have been considered at one time for other applications. Emphasis

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*With a McCulloh loop as many as 45 code transmitters may be used. Some newer equipment may include up to 90 transmitters.

was placed on techniques that have potential for simplicity and low cost, with, hopefully, minimal sacrifice of reliability.

Prior to this study, four media had been the subject of investigations by Aerospace and others. The first uses cross-town power transmission lines as a medium for carrier modulated data. Some electric utilities, primarily in the eastern United States, are interested in developing this communications medium for remote utility meter reading, system switching, and peak-load-control applications. A few companies have developed and demonstrated techniques that show some promise, but recently these development efforts have been suspended for economic reasons.

A second communication medium investigated is the two-way or interactive TV cable system. The medium is being developed under an FCC directive, which states that all new systems in the top 100 CATV markets shall maintain a plant having a technical capability for non-voice return communications. A requirement for conversion of older, one-way systems to two-way capability is being resisted by CATV operators. Thus, an important consideration in using this medium is the expected coverage of two-way CATV systems of the United States during the time frame of interest.

A third communication medium is the telephone network, in which alarm signaling is adapted to operate over the carrier multiplex telephone plant. Two major categories of operation are (1) dedicated-channel and (2) switched. The dedicated channel approach uses "bridges" to bypass the central office switching equipment. The switched approach includes use of automatic dialers. A variation of the switched category would require that the telephone company perform some of the line monitoring functions presently carried out by alarm companies. However, acceptance of this approach by telephone companies may not be forthcoming because of their policies.

A fourth medium for consideration is the RF transmission of alarm data directly from a residence or business to either a police dispatch car, a police station, or an alarm response company. Experiments with several systems under LEAA sponsorship are under way; they are supervised by local police agencies and the companies who developed the equipment. These systems suffer from common problems (i.e., normal police or data traffic interference, noise interference, poor equipment reliability, lack of verification of system operability, less than optimum frequency allocations, and high cost).

B. Cross-Town Power Lines

1. Introduction. The principal factor in favor of considering the use of this medium for alarm signal transmission is its accessibility to virtually all households and businesses. Another positive factor is the expressed desire (and preliminary plans) on the part of some utilities, primarily in eastern United States, to implement some form of remote reading of utility meters, with cross-town power lines being considered as one of several possible transmission media. It has been argued that the system requirements for remote meter reading via power line carrier are not vastly different from those for alarm traffic transmission, and that a combined meter-reading/alarm-transmission system could offer significant cost benefits compared with the costs associated with competing communications media.

Power line networks do not readily lend themselves to analytical treatment as a communications medium because of the complex interconnections, fluctuating loads, difficult-to-predict resonance or anti-resonance conditions at RF carrier frequencies, and unpredictable noise sources, both natural and man-made. Experimental methods are required in analyzing RF carrier transmissions over such networks and such experiments were outside the scope of the SRI study. Thus, this study had to rely on material published in the open literature and obtained from interviews conducted by SRI personnel with technical, administrative and management personnel of electric utilities, primarily the Pacific Gas and Electric Company (PG&E).

2. Description of the medium. Comprehensive descriptions of the general characteristics of electric power transmission and distribution systems are contained in the Data Package.[1,2*] The principal elements

*References are listed at the end of the report.

400 distribution transformers. One distribution transformer may serve from four to about 15 residential customers. Even large numbers of customers per distribution transformer are found in the case of underground circuits (up to 50 residential customers per primary underground radial tap). Within large cities feeders seldom exceed 1 to 1-1/2 miles in length; within suburban areas the average lengths of feeders may be about 2.5 miles. The length of feeders in rural areas may extend up to 50 miles. Most suburban and rural feeders today use overhead wiring; however, the trend is toward increased undergrounding of the distribution networks, primarily in urban and suburban areas. Modernization of the distribution networks frequently includes increasing the feeder voltages; for example, no new 4-kV feeders are currently being built in Northern California.

(b) Devices along a feeder. If alarm signaling via cross-town power lines were to be implemented, the distribution feeders would represent the major part of the transmission paths. Thus, the devices and components of the distribution networks that are found along feeders must be examined for their effect on RF carrier signal transmission. Such devices include voltage regulators, disconnect or sectionalizer switches of various types (including air switches), fuses, power-factor-correction capacitor banks, autotransformers used to boost the line voltage (especially on long feeder lines), and the final distribution transformers. The most important of these devices--from an RF carrier transmission point of view--are disconnect (sectionalizer) switches, capacitor banks, and distribution transformers.

Disconnect switches are used to disconnect feeder segments from one feeder and transfer them to another feeder, to be supplied by a different transformer bank, and sometimes even by a different substation, in accordance with power-demand, load-balancing, and maintenance

of the distribution networks that were of interest in this study as potential data transmission links are the distribution feeders. Signal losses that would be encountered across substation transformers as well as the high costs of coupling of communication system components to high voltage transmission lines render the use of the transmission/distribution system beyond distribution substations impractical for alarm signal transmission.

(a) Distribution feeders. Distribution feeder voltages typically range from 4 kV to 34.5 kV. Most distribution feeders in the United States are three-phase.

There are two common types of distribution feeder systems: radial and "network." In a radial system, the distribution feeders emanate radially from a distribution substation; thus, at any given time there is only one electric path between a substation transformer and customer's meter. Radial distribution systems are ubiquitous, except in downtown areas of a number of major U.S. cities, where network systems are used. In network distribution, a number of substation transformers and feeders are connected in parallel. The capacity of the feeders and their number (used in parallel) are selected so that failure (or removal from service) of any one of the parallel feeders leaves enough distribution capacity intact to fully supply the maximum expected power demand of the network. Networks designed on a "single contingency outage basis" usually employ from three to five parallel feeders. The parallel-path configuration of the urban distribution networks strongly suggests the possibility of multipath effects if this medium were to be used for RF carrier communications.

The number of customers supplied by a single feeder may range from one large industrial customer up to about 4000 households. A typical feeder in a suburban area may serve 3000 residential customers via, perhaps, requirements. Entire feeders may also be switched, in the same fashion, from one transformer bank to another. Thus, electric utilities cannot guarantee a unique, invariant transmission path between a subscriber's premises and a substation.

Capacitor banks are used across industrial or residential loads, which are partially inductive, to correct the power factor and thus to improve the efficiency of the distribution system. These capacitor banks are switched across the feeders, as needed, either remotely or locally by either clock, voltmeter, or VARmeter. Such capacitors, when connected, present extremely low-impedance shunt paths at radio frequencies that might be used for alarm signal transmission (60 kHz to, perhaps, 300 kHz). There are documented cases in which the switching in of a power factor correction capacitor bank totally disabled telephone circuits operating via power-line carrier.[3]

Distribution transformers. A recent series of measurements of RF signal attenuation across a standard utility distribution transformer showed voltage attenuation of about 20 dB in the upward direction, and about 40 dB in the downward direction across the transformer in the RF range of interest (from 60 kHz to about 300 kHz).[2] This attenuation could be a severe problem and may require the use of repeaters.

3. Limitations of the medium for RF carrier communications. The RF energy injected into a power line at a subscriber's premises is subject to losses from its being:

- Dispersed into unwanted network branches at the subscriber's household, as well as at neighboring households supplied from the same final distribution transformer.
- Attenuated across the final distribution transformer.

- Dispersed into unwanted network branches across all other final distribution transformers on that feeder.
- Subject to reflections, resonance, and antiresonance* conditions on the line and its branches.
- Subject to attenuation and/or signal blockage by various devices and components found on distribution feeders (discussed in the following subsection).

Additionally, the signal must overcome the inherently high noise levels, both natural and man-made; also, switching of feeders may result in unexpected variations (lengthening) of the signal path. Therefore, the RF signal power injected into the power line must be of sufficient magnitude to overcome all the above losses and still produce adequate signal-to-noise ratio at the receiver at the distal end (presumably at or near the substation). Finally, modernization of the electric distribution systems, with the concomitant trend toward increased undergrounding of facilities and higher feeder voltages may present additional obstacles to the implementation and the maintenance of RF carrier communications via cross-town power lines.

The problems cited above are unique to the cross-town power lines medium and result from the fact that the medium was designed for a totally different purpose than RF signal transmission, namely efficient distribution of electric power to utility customers. Thus, many features and characteristics of this medium that are desirable from the power transmission point of view may be detrimental for RF carrier communications, and vice versa. The technical solutions would have to involve communications system designs that are tailored to the specific characteristics of given power line networks, including careful selection of carrier frequencies, provision of adequate transmitted power to overcome losses and produce adequate signal-to-noise ratio, and probably the use of repeaters (amplifiers) en route.

*Resulting in loss of signal or in radiation from the power line.

4. <u>Remote meter reading--status</u>. In the past few years utility companies in the United States have demonstrated interest in development of a system of remote reading of utility meters.[4,5] At first glance, the technical requirements for remote meter reading systems do not appear too different from those for alarm signal transmission. Consequently the security systems community is disposed to consider possible joint or shared operation of such systems by utilities and the alarm industry.

Power line carrier communications is not the only medium considered for this application. Telephone lines, CATV systems, and even radio systems also have been considered for remote meter reading.

SRI conducted an extensive literature survey, including technical and trade journals, and contacted various organizations involved in development and/or testing of remote meter reading systems via power lines. The following is a summary of findings resulting from the survey:

- A number of utilities and remote meter reading system developers have developed prototype equipment and conducted limited testing of transmission of digital data via power lines, including transmission across power transformers. These limited tests were generally successful. Detailed technical test results are not available to the public.
- Follow-on, larger-scale system tests including perhaps 1000 utility meters per test system are required to verify both the technical and the potential future economic feasibility of such systems.
- Follow-on tests have been suspended indefinitely, primarily because no economic justification* can be found at the present for implementing remote utility meter reading.

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*Current costs of manual meter reading range from $2 to $8 per meter per year,[6] while current estimates of the cost of remote or remote/automatic meter reading range from $15 to in excess of $30 per meter per year.[6,7]

- Due to the unpredictable behavior of power line networks at radio frequencies, implementation of RF carrier communications may involve "custom tailoring" of the communications equipment to the line.
- Remote meter reading systems would require repeaters along the feeders to compensate for losses and attenuation across transformers and capacitor banks.
- RF signal transmission over power lines is subject to interruption because of load changes, noise (both man-made and natural), weather conditions and many other factors. This interruption does not necessarily disturb the meter reading function, since meters generally need to be read only about once per month and a missed reading can be obtained later. However, such interruption of transmission capability is totally unacceptable for alarm signal transmission.
- The data rates that are possible, with acceptable error rates, over power lines are relatively slow. For example, usable data rates quoted by General Electric Company (GE) range from 30 to 120 bits/sec.[4]
- Other competing transmission media, in particular phone lines and CATV, offer better reliability and much higher data rates. The principal reason for continued interest in power lines by the utilities is that they own and thus are able to control the transmission medium.
- Future resumption of development of RF carrier communications systems by electric utilities is likely to include, in addition to remote meter reading, other multi-function, utility-oriented applications, such as (1) network switching and control, including remote control of capacitor banks, switchgear, etc.; (2) peak load shaving through remote control of water heaters and other loads that can be shifted in time.

To summarize, system requirements for remote meter reading are quite different than those for alarm signaling applications. In particular, <u>meter reading</u>:

- Need take place only when feeders are switched into "normal" configuration.
- Need not take place during periods of high RF noise.

- Requires correlation of errors only on a month-to-month basis.
- Requires relatively low data rates (of the order of a few million bits per day).

On the other hand, alarm signaling:

- Requires the capability to transmit and receive at all times.
- Requires immediate resolution of errors.
- Requires relatively high data rates, especially for polling systems.

While the implementation of remote meter reading (although not necessarily of alarm signal transmission) via power lines does not appear to be technology-constrained, the current economic constraints make its widespread implementation in the next decade highly unlikely. In the absence of such systems, the alarm industry, if it were interested in developing the cross-town power lines as a communications medium for alarm signal transmission, would have to carry the cost of implementing such a system. Moreover, the alarm industry would have to obtain consent and cooperation of electric utilities, which, as will be shown is likely to be unobtainable.

5. Cost factors. The electric utilities as well as the developers of remote meter reading systems have refused, for proprietary reasons, to release to SRI technical and cost data for the systems under development. Thus, the equipment and operating costs for RF carrier communication via power lines could not be obtained. In view of the constraints on the use of the power lines medium, as shown in two following subsections, it was deemed unnecessary to go to great lengths to generate such cost data, since the availability of this medium for alarm signal transmission was ruled out for reasons other than cost.

6. Regulation and policy. Two policy and regulatory areas are of primary importance to alarm signal transmission via power lines. The firs concerns the technical safety standards and their implications for connect-ing devices such as repeaters, bypass capacitors, and transmitter/receiver modems to the power lines both at subscriber's premises and to high-voltag feeder circuits. The second deals with the current policies of the electric utilities regarding the use by others of power distribution networks for purposes other than its original intent.

(a) Electric codes and safety standards. The design and construction of the entire power distribution system up to the residential meter box is under the control of the utility company and its regulating authorities. From the meter box on, the installation of household wiring is controlled by electrical codes.* These include state and local codes, which conform fairly well to the National Electrical Code, published by the National Fire Protection Association. While the National Electrical Code has no controlling or regulatory authority, it is used as a very comprehensive standard on which state and local codes are based.

The design and construction standards for utility-owned distribution systems are based on the standard utility practices, which are regulated by the state administrative codes. These specify, among others, standards for grounding and insulation, separation between conductors, safety and protection requirements, such as fuses and circuit breakers. The standard practice and codes impose rather costly requirements for coupling of devices such as bypass capacitors, repeaters, and modems to high-voltage feeder circuits.

*For further discussion of electrical codes, the reader is referred to Reference 2.

(b) Utility policies. During this study SRI conducted extensive interviews with senior engineering and management personnel of one of the major electric utilities to pinpoint the presently existing policies that may have an impact on the use of the power lines medium for alarm signal transmission, as well as to solicit opinions on how these policies may evolve in the presence of potential public demand for low-cost communication media. Although this information was obtained from only one electric utility company, similar policies are undoubtedly in effect throughout the electric utilities industry throughout the United States. The following points summarize SRI's findings:

- The principal purpose of an electric utility is to supply electricity to residential, commercial, and industrial customers. Anything that could potentially interfere with customer service or degrade its reliability cannot be tolerated. This includes connecting of devices that might reduce the power distribution system's reliability or cause interference with customer service (including, e.g., interference with the customer TV reception).
- Any part of the distribution system on the utility's side of the customer's meter box is the responsibility of the utility, and must meet the utility's safety standards and standard practices. Also, as a rule, installation and maintenance of any equipment connected to utility-owned power lines is generally performed by the utility company's maintenance personnel.
- Most electric utilities in the United States have never in the past provided the type of service that would be necessary for alarm signal transmission, and they would be extremely reluctant to provide such service in the future, for the following reasons:
  - Possibility of legal liability, under the "implied warranty" rules, once alarm signal transmission is permitted and implemented. If the utilities were subsequently to discontinue such service, for

technical or other valid reasons, they might find themselves under a legal obligation to continue this service, in spite of possible hardship to the utility.
  - Fear of increased regulation. The electric utilities are currently regulated by the public utilities commissions, and the state administrative codes. If they were to provide service as a communications medium, they might fall under the jurisdiction of the Federal Communications Commission, as a common carrier.
  - Possible interference with the normal operation and customer service. Connecting of repeaters, bypass capacitors, and other devices to high-voltage lines might result in decreased reliability of the power distribution system and increased maintenance requirements through increased frequency of outages. Also, RF carrier signals might cause interference with the customer TV or radio reception, or with the operation of other types of customer equipment.
  - Finally, the utilities see no significant increase in their revenues, or any other financial benefits arising from providing such service.

Thus, for all of the above reasons the utilities are expected to resist any attempt on the part of the public or government agencies to induce them to permit the use of cross-town power lines as a medium for transmission of alarm traffic.

7. Conclusions and recommendations. In view of the anticipated technical difficulties in implementing an RF carrier system operating via power lines that is suitable for alarm signal transmission, as well as the likely resistance, or refusal, on the part of the electric utilities to permit implementation of such systems, the following conclusions and

C. Telephone

1. Introduction. Initially, the alarm industry installed and operated their own circuits from the protected premises to the alarm central station. In time this gave way to reliance on the facilities of the telephone companies, a practice that is common today.

In the past, telephone company charges for alarm signal transmission were generally lower than were rates for voice services since the alarm industry could utilize sub-voice grade lines, such as metallic pairs, without the necessity (and added cost) of including repeaters or load coil Such special rates for alarm signal transmission over metallic circuits ar still available in many locations. These rates are expected to be increased to be the same as the rates for data transmission because the cost of installation and maintenance is identical for all local loops. In addition, metallic interoffice trunks are being replaced with carrier systems that are incompatible with dc signal transmission. As a result, the telephone companies now require that the users operate within the nominal voice bandwidth, as specified by the Series 3000 tariffs.* Thus, the alarm industry will be forced to discontinue dc alarm signal transmission.

2. Description of the medium. The customer-provided alarm signaling equipment has required lines with metallic continuity, due to the direct-current nature of existing alarm and supervisory signals. However, with the introduction of carrier systems, it has become uneconomical for the telephone companies to provide such wire lines, especially for interoffice service. Recently, AT&T Company stated that they have no obligatio to continue to provide private line channels on a metallic basis, and in

*Bandwidth: 300 to 3000 Hz.

many metropolitan areas new orders for metallic circuits are no longer accepted where interoffice circuits are involved. The alternatives available to the alarm industry include voice-grade data service (Series 2000* or 3000) or teletype (Series 1000) circuits. As the result of the above changes in the regulatory environment and the advances in technology, the following changes in the operation of the telephone system are considered of importance to the alarm industry:

- Gradual phasing out of metallic-continuity dc circuits between central offices.
- Replacement of interoffice circuits with voice-grade circuits available under Series 3000 tariff.
- Probable discontinuance of wire pairs with metallic continuity within a central office area.†
- Replacement of the currently available special rate for alarm services with standard Series 3000 rates in all areas.
- Availability of specially designed active bridges.
- Installation of electronic central offices (ESS) and tone dialing that will provide new customer services such as call forwarding, abbreviated dialing, automatic number identification, etc., which could be used for improved dial-up‡ alarm services.

*Series 2000 is basically designed for voice communications, although occasionally it has been used for data transmission.

†However, some telephone companies (e.g., Pacific Telephone & Telegraph Company) anticipate a continuation of this service in the immediately foreseeable future.

‡In a dial-up alarm service, the connection is made over the standard telephone switching network, either manually or automatically (using an auto-dialer).

3. Alarm applications. Alarm signals are transmitted over commercial telephone circuits in one or the other of two general ways. The first uses permanently connected lines or channels between the subscriber's premises and an alarm central station; the circuits bypass the telephone company's central office switching equipment. This method is termed a "dedicated system." In the second, there are no permanent connections between the subscribers and the control station, and the system utilizes the telephone company's switching equipment; this is termed a "switched system."

Figure 2 is an exhaustive summary of possible categories and subcategories of dedicated and switched telephone systems that can be used for transmitting alarm signal messages. The various systems are discussed below.

(a) Dedicated systems. Dedicated systems can be classified according to the type and geometric configuration of the transmission channels as follows: (1) wire lines, (2) subscriber carriers, and (3) tree/loop-type systems.

(1) Wire lines. For this analysis, wire lines are defined as circuits relying exclusively on physical wire pairs. Frequently, these types of lines are also referred to as metallic circuits. The wire lines can be subdivided into three classes: (a) ac or dc loops, (b) circuits utilizing multiport "open-window" bridges, and (c) circuits utilizing multiport "closed-window" bridges. As seen in Figure 2, both "open-window" and "closed-window" bridges are used with ac carrier systems as well.

Dc loops. These systems include direct connections (wire pair) and series loops.

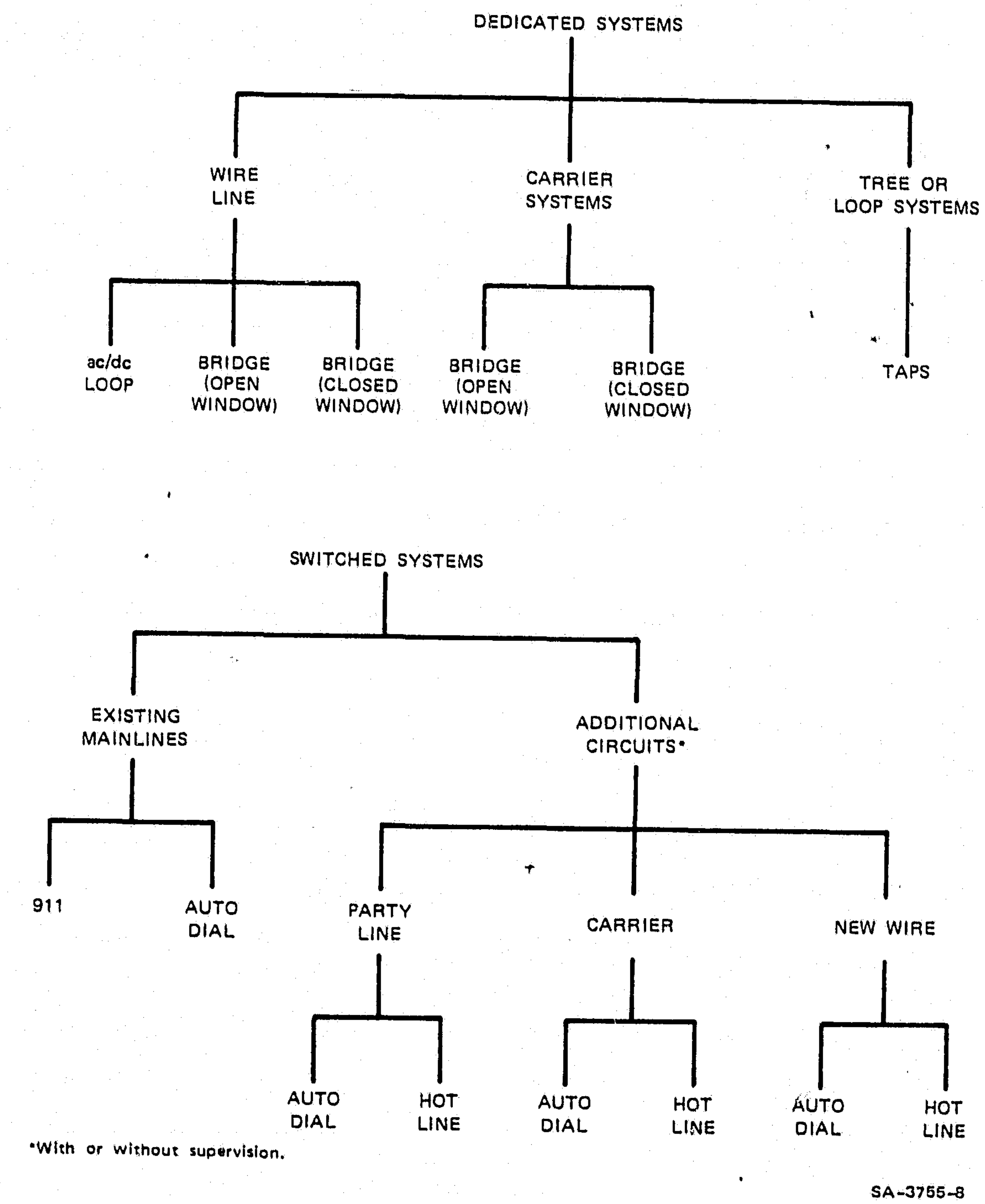

FIGURE 2 ALARM SYSTEMS VIA TELEPHONE LINES

Direct connection. In direct connection, each subscriber is connected by a leased private-wire line or channel to the alarm central station. When an alarm signal is received at the central station, a visual or audible indicator, or both, indicate the source of the alarm. A variety of techniques are used to supervise the transmission lines by providing an indication whenever a failure of the channel occurs.

Series loop. Another commonly used transmission system is the series connection of subscribers' alarm units. Here, instead of individual wires to each protected premise, the subscriber's premises are connected in a series arrangement. One of the most common loop circuits is the McCulloh loop, which serves 25 or more subscribers. Each subscriber in the loop circuit has a transmitter unit that transmits a code to the central station whenever the alarm is activated. Personnel on duty in the central station can determine where the alarm originates by decoding the signal received. There is no restriction on how many loop circuits a central station may employ. Each loop requires a separate communications channel.

Ac circuits and bridges. With conversion from dc to ac signal transmission, it is no longer possible to use simple series or parallel connection of metallic wire lines. Ac circuits require proper line impedance matching. Thus, it is necessary to use bridge-type circuits, which split the line in as many ports as needed without disturbing the line impedance characteristics. The bridges permit operation in a time- or frequency-division-multiplex (TDM or FDM) mode. TDM is a more common method used by the alarm industry. Bridges can be cascaded to increase the number of subscribers in a single system.

The first bridges offered by the telephone company were small passive two- or four-wire bridges with four or six ports

(e.g., points for subscriber connection). The small bridges are not very useful when applied to large systems where many bridges have to be cascaded; the resulting high signal loss has to be compensated with external amplifiers.

In answer to the above problem, R. D. Hailey of the Pacific Telephone and Telegraph Company (PT&T) developed a special multiport active bridge operating on voice frequency data channels providing as many as 128 ports. A major characteristic of the Hailey bridge is that each of the subscriber ports operates in a two-wire mode and the main input port in a four-wire mode. The Hailey bridge is currently available to subscribers. It eliminates the loop-length constraints of the dc loop and enables the alarm companies to locate a central alarm station in any convenient location. Alarm points many miles away can be monitored readily via a conventional Series 3002 voice-grade leased line.

With proper coding, voice-frequency circuits operated with multiport bridges exhibit good resistance to tampering. However, the system is not jam proof. Accidental or deliberate injection of noise at any of the bridge ports (i.e., any of the subscriber premises or lines) can mask alarm signals generated at any of the other ports on the bridge.

This weakness has been recognized by the alarm industry and AT&T. As a result, AT&T through their Bell Telephone Laboratories is currently developing a "closed window" (switched) four-wire active bridge with 128 ports. In this new bridge, a central alarm processor can remotely control, via a separate control channel, the opening and closing of ports. Thus, accidental or deliberate noise injection at any input line to the bridge will not jam the system, and at the same time, a noisy line can be readily identified. The AT&T bridge can be cascaded, providing loss free as many outlets as the system can handle.

While all types of telephone bridges can be used as an alternative to or replacement for hard-wired alarm circuits, the active bridges offer better flexibility. The best of these, in terms of resistance to tampering, is the AT&T "closed window" bridge. This bridge is still under development. It is expected that it will be offered for service during the last quarter of 1976.

(2) Subscriber carrier systems. In recent years, the costs of electronics, and especially that of active components, have dropped dramatically, while the installation and basic costs for cables have increased steadily. Thus, subscriber carrier channels are becoming economically competitive at increasingly shorter distances when compared to individual wire circuits. This is true particularly in major metropolitan areas where duct space is at a premium and the installation of new cables becomes extremely costly. The use of subscriber carrier channels for alarm signal transmission is becoming an attractive alternative because the already existing subscriber telephone circuit can be utilized.

The subscriber carrier can be used in conjunction with the ac bridge systems.

(3) Tree- or loop-type systems. Connecting multiple subscribers, via taps, to a single ac channel either in series (loop-type) or in parallel (tree-type) may offer significant cost advantages in areas with high subscriber density. However, because such network arrangements do not conform to present standard telephone practices they have not been investigated in great detail.

(b) Switched systems. In a switched alarm system there is no direct and permanent connection between the alarm points and the alarm center. Thus, whenever an alarm condition exists, a connection between

the originating point and the receiving point has to be established through the telephone switching network. Because the emphasis in this study has been placed on transmission of alarm signals that are actuated automatically, the principal equipment of interest in this category is the auto-dialer.

(1) 911 emergency dialing system. This system allows an individual to request assistance, for any type of emergency, requiring either police, fire department, medical, or other source of aid, simply by dialing this three-digit number. Because of the possibility of false alarms and misuse, the use of 911 in conjunction with an auto-dialer has been banned by most public safety agencies. Therefore, this system cannot be used for automatically generated alarm signals.

(2) Auto-dialer. A more appropriate approach for using auto-dialers is in conjunction with alarm companies or other response agencies. An auto-dialer system connected to an alarm company could be recognized by a central computer with the proper exchange of code and identification words. Thus, misuse or abuse could be minimized.

In principle, the auto-dialer, combined with automatic identification, represents the simplest and potentially least expensive form of alarm system. A major drawback of this type of system is that there is no line supervision. A limited degree of line supervision can be provided by automatic, periodic self-reporting (e.g., once or twice per day). This type of limited line supervision appears to be adequate for protection of low-value premises such as low-to-middle income residences and small businesses; it is not adequate for protection of high-value premises (e.g., banks, jewelry stores, etc.).

For any dial-up service, it is theoretically possible to provide centralized line supervision. However, that would require

(1) additional capital investment by the telephone company, and (2) the telephone companies to perform functions that are normally considered to be a responsibility of the alarm companies. Neither of the above requirements is acceptable to the telephone companies.

Another drawback of using existing subscriber loops for alarm services is that if a subscriber line is in use or being called, it is not available for alarm transmission. To overcome this problem, equipment has been developed to disconnect an on-going call and seize the line. Of course, such improvements result in increased equipment costs.

A higher degree of reliability could be obtained with auto-dialer systems if they were to operate over additional assigned telephone channels. However, the cost of additional leased lines obviates the primary cost-benefit feature of auto-dialers, i.e., no line costs.

One type of simple auto-dialer is currently offered for lease by the telephone companies. Various types of more sophisticated and complex dialers are available from private manufacturers. However, for all non-telephone-company-supplied dialers, the telephone companies require installation of an interface device (coupler) between the dialer and the telephone line, at an added cost. The need for this device is currently disputed by the manufacturers of telephone interconnect devices (including auto-dialers). Currently this device is required for non-telco equipment in all states, with the exception of California, where recently (on 22 April 1975) an interim order was issued by the Public Utilities Commission, which provides for direct connection of certified ancillary equipment,* thus removing the requirement for the coupler. This ruling is being challenged by the telephone company in court. The final results are therefore uncertain. Even if approved, it is uncertain if and when other states will follow suit.

*This ruling does not include telephones and PABX equipment.

Although a great variety of auto-dialers offering a diversity of features is currently on the market, a set of specific requirements for auto-dialers specially designed for large-scale alarm signaling applications needs to be determined.*

4. Cost factors and systems approaches. The following ground rules or assumptions were established for the comparative cost analysis of exemplar candidate system concepts.

- Dc loops will be discontinued and all systems will operate on a Series 3002-voice-grade channel.
- From the assumption above, it follows that all interface points with the telephone system require a modem. It is recognized that in some locations, dc circuits are still available, and thus for some systems no modems would be required, and also the line costs could still be lower. However, ultimately the special services for alarm companies will disappear and all systems have to be converted to the new ac-type of structure.
- Leased line tariffs are based on current PT&T tariffs. The line charges may be different in other states, but generally the differences are minor. Current leased line tariffs for alarm systems in California† are:
  - Subscriber leased line, type 3002--$3.50/month.
  - Central station trunk line lease (full duplex)--$7.00/month.
  - Central station trunk line termination (serves 63 leased lines)--$5.00/month.
  - Installation cost for each local loop termination--$20.00.

*During the data gathering phase of this study, several sources, including one alarm company, suggested that combining in an auto-dialer the automatic burglar/fire alarm with a request-for-aid button (e.g., for medical aid) would find wide acceptance, especially among the elderly living alone.

†Source: Reference 11 and California PUC/PT&T tariffs.

5. Regulation and policy. The policies of the telephone companies and the regulations set by the FCC and public utility commissions have a considerable bearing on the type of systems and equipment used by the alarm industry.

For the alarm industry, the discontinuation of the metallic wire lines service and the associated low-cost special alarm circuit rates, has considerable impact. It necessitates the installation of new systems and increases transmission costs.

Another item of importance is the requirement for an interface coupler for all non-telephone company-supplied equipment. Under this requirement the alarm companies may be forced to pay for data access arrangements (DAA) at all line termination points. However, independent equipment suppliers are exerting efforts to be relieved of this requirement or to have a simpler equipment certification program substituted for it. The certification program would be of major importance for manufacturers of auto-dialers, since it would make their equipment more competitive to that supplied by the telephone company. In Reference 8, several feasible possibilities for centralized line supervision are described. However, implementation of any one of these possibilities is politically difficult since they place a decision-making responsibility into the hands of the telephone company, which is a responsibility beyond the mandate of a common carrier. Under the circumstances, unless the mandate is changed by regulation, the telephone companies can be expected to shy away from the responsibility of participating in the operation of an alarm system.

6. Conclusions. All alarm systems fall into either of two categories, dedicated or switched, with the latter including auto-dialers.

Dedicated systems are more costly but provide a much greater reliability and security than the auto-dialer system. Therefore, in commercial

operations where security is of prime concern, dedicated systems are used almost exclusively. However, for home alarm systems, the auto-dialer approach using the subscriber's regular telephone line is the most promising due to its simplicity in installation and its low cost.

For the cost analysis the following system approaches were selected:

- Dc McCulloh loop
- Ac direct-connect lines
- Ac digital system
- Telco auto-dialer
- Non-telco auto-dialer.

It was found that, among the three dedicated systems, the McCulloh loop operating on metallic lines was a very effective and low-cost system. However, since metallic lines will no longer be available in some areas, a direct-line conversion to ac and a multiport-bridge multiplex system were selected as representative examples for the cost analysis.

Existing and proposed central office bridges provided by the telephone companies offer a suitable replacement for current dc UL-approved systems. Of particular interest is the "closed-window" bridge under development by Bell Telephone Laboratories, since it will offer better systems reliability and systems simplification.

The auto-dialer shows the best promise for low-cost home alarm systems, although some problems may still exist, including low reliability and the resistance of some police departments in accepting this form of alarm service. Although many of the desirable features for low-cost alarm service may already have been incorporated into some existing auto-dialers, the "optimum" dialer for this service has not been specified; some improvements in reliability may be necessary.

The current requirements for telephone-company supplied couplers between non-company auto-dialers and the telephone plant significantly increase the cost of the non-telco dialer systems. The need for such coupler should be reexamined.

D. Cable Television

1. Introduction. CATV is a broadband coaxial cable system designed primarily to carry TV signals. It was originally developed as a one-way transmission medium to satisfy the demand for TV reception in poor off-the-air reception areas. However, systems operators are interested in expanding the service capability of their systems. The services that are proposed include such interactive services as pay-TV data transmission, opinion polling, and a variety of commercial, educational, and computer applications. One of the many services proposed is the provision of alarm transmission. A prerequisite for the implementation of interactive services, including alarm service, is the availability of two-way transmission. In view of these possibilities for expanded capability of CATV, the equipment industry has spent millions of dollars to develop and demonstrate the necessary transmission and terminal hardware. However, so far the market acceptance has been almost non-existent. This is due primarily to the limited penetration of CATV in the major metropolitan areas. However, it is expected that the demand for these expanded services will ultimately provide a higher penetration rate and make CATV a new major local common carrier.

Between 1968 and 1972, the CATV industry invested large sums in perfecting the technology for home terminals and two-way transmission. Among the services proposed and demonstrated were alarm systems. Test installations were also conducted in various parts of the country and further installations have been placed. Table 1 presents an overview of the manufacturers who have developed interactive transmission systems for CATV. Most of these systems have been successfully demonstrated at conventions or in actual pilot field installations. Although the tests proved the capability of the technology, the lack of market acceptance remains a major obstacle to the proliferation of interactive CATV systems.

Table 1

INTERACTIVE CATV TRANSMISSION SYSTEMS

System Name	Manufacturer	Location	Test Location	Type of Subscriber Terminal	Cost
Computer Cinema	Computer Cinema	New York, New York	Newark, New Jersey	Converter, encoder	--
TOCOM	TOCOM Manufacturing	Dallas, Texas		Converter with 3 buttons added	$100
Conserve	RCA (EIE)	North Hollywood, California	Orlando, Florida	4-button control, A-B switch, modem	100
Subscriber Response System (SRS)	Theta-Com/Hughes	Culver City, California	El Segundo, California	4-button console, modem 17-button console, printer, modem	150 250
Queser	Vicom Manufacturing	Ann Arbor, Michigan	Overland Park, Kansas	12-button console, modem	280
Security Alert System	Scientific Atlanta, Inc.	Atlanta, Georgia	Crystal Lake, Illinois	Alarm interface	100
6400 two-way digital communication system	Scientific Atlanta, Inc.	Atlanta, Georgia	Monroe, Georgia	Alarm interface, 5-alarm circuits	125
Hol-Com	Holmes Communications Corp.	New York, New York		Alarm interface	200
Versacom	Advanced Research, Inc.	Atlanta, Georgia	Pensacola, Florida	Alarm interface	100
TICCIT	Mitre Corporation	McLean, Virginia	Stockton, California Reston, Virginia	17-button console, modem	200
Community Information Systems	General Electric	New York, New York	Jonathon, Minnesota	12-button console, modem	--
CSC System	Coaxial Scientific Corp.	Sarasota, Florida	Columbus, Ohio	Tone-modulated transmitter	20
Video 12	Video Information System	New York, New York		12-button console, modem	252

2. <u>Description of the medium</u>. A CATV system uses a variety of equipment to receive, process, and distribute electronic signals (i.e., video, audio, and data) to subscribers. The system must include:

- A head end with receiving antenna(s) and associated signal processing equipment.
- A cable distribution network.
- Subscriber drops and terminal hardware.

The coaxial cable distribution system fans out like a tree from the head end and passes all the households in the franchise area (see Figure 3). A complete description of various systems approaches to CATV can be found in Reference 9.

In the early days of CATV, single-channel systems were not uncommon. A received television signal was piped in coaxial cables from the remote head-end site to individual subscribers. As more channels become unavailable to the system operators, additional channels were placed on the existing facilities since the coaxial cable has wideband characteristics. This practice has increased the capability of CATV systems from a single channel to 5, 12, 20, and as many as 42 channels on a single cable. At present, 12-channel systems are the most common; however, many new systems have at least a 20-channel capability. The most commonly used system is based on a frequency division multiplexing (FDM) approach. The system layout uses three types of coaxial cable and associated electronics:

- Low-attenuation, 3/4-in. coaxial cable equipped with low-distortion, low-noise amplifiers for major trunk lines.
- Medium-attenuation, 0.5- or 0.412-in. coaxial cable equipped with more economical amplifiers for the distribution lines.
- Small-gauge (RG-59/U) coaxial cable for short runs from the directional tap to the subscriber terminal.

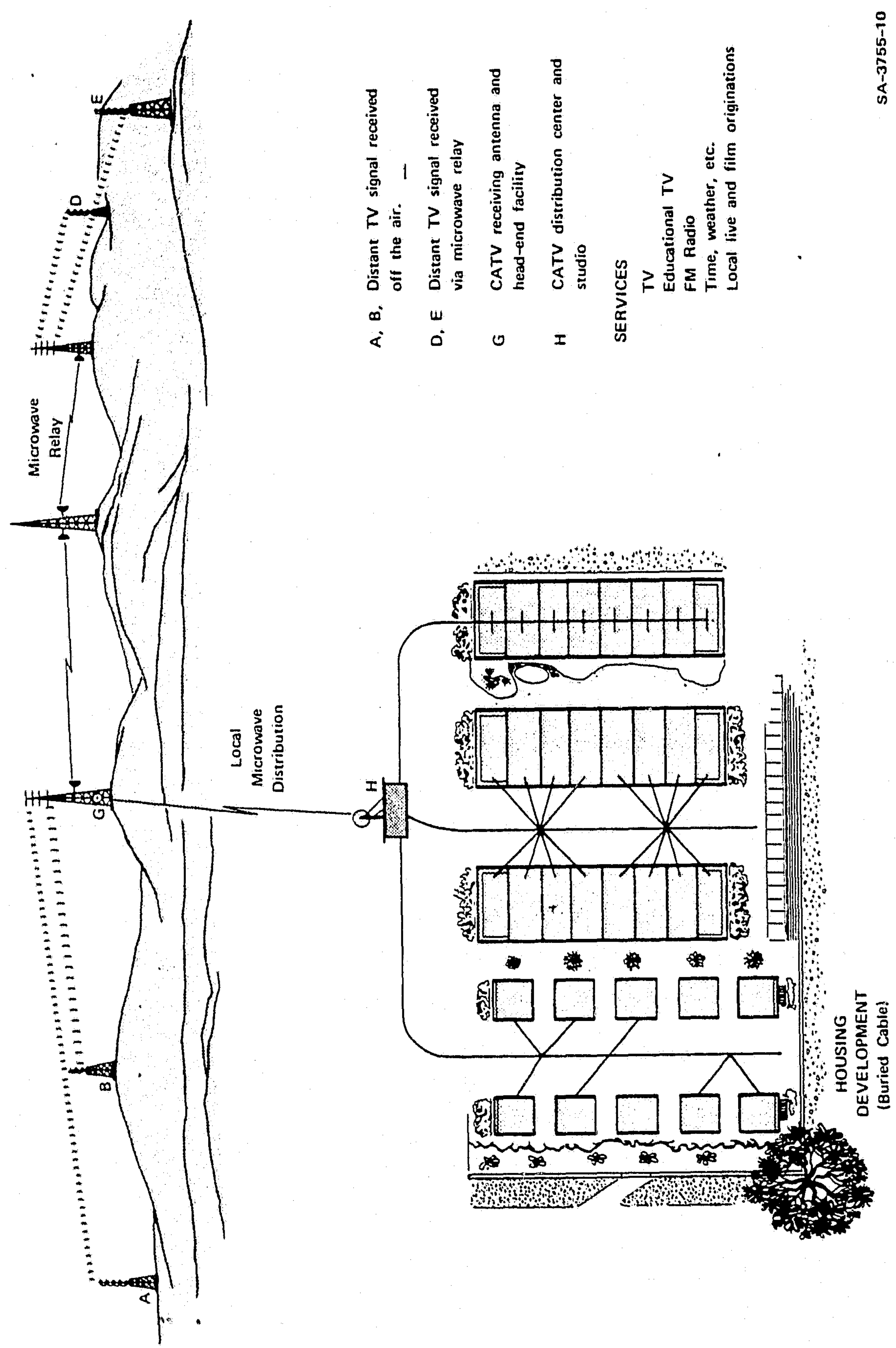

FIGURE 3 CATV SYSTEM FOR SUBURBAN AREAS

The major investment in a CATV system is the cable distribution facility that carries the electronic signals from a central location or the head end to the television receivers of the individual subscribers. In addition to the trunk and distribution cables, the distribution system contains trunk and distribution amplifiers (also line extenders) that must be inserted at frequent intervals to compensate for line and distribution losses. Typically, the amplifiers are placed at 22-dB line-loss intervals. The system layout is usually determined by the topography, cost of cables, and the electrical characteristics of the broadband amplifiers.

Rural CATV systems usually supply only a few video channels. However, in metropolitan areas, CATV systems must have a capability of 20 channels, or more, in order to meet the potential demand and to satisfy the FCC regulations. These systems utilize the existing 12 VHF channels over the 54- to 88-MHz and the 174- to 216-MHz bands as well as the nine mid-band channels from 120 to 174 MHz. To receive the mid-band channels and to utilize all of the 12 conventional channels, a set-top converter is required for the subscriber's TV receiver. This converter acts as a channel selector that converts all 20 video signals to an unused local channel for input into the TV receiver. An additional 9 to 14 channels can be made available by also using the superband between 216 and 300 MHz.

Another major requirement specified by FCC rules is the capability to provide two-way transmission in the major market areas. In view of this fact, most of the CATV broadband amplifiers currently on the market have built-in options for conversion to two-way. The normal procedure is to insert separation filters at the input and output of each main-line amplifier and an additional amplifier for reverse line operation. Usually, the filters are designed to separate the sub-low-band frequencies from the frequencies above 54 MHz. This approach provides reverse transmission capability for up to eight video channels below 54 MHz. Most CATV experts consider this bandwidth to be adequate to accommodate upstream video transmission from selected points and upstream signaling of responses or alarms from individual subscribers. A CATV system with these extended communications capabilities is illustrated in Figure 4.

One other important aspect for the utilization of CATV for alarm transmission is system availability. As of 1972, about 10 percent of the households in the 153 largest cities were fronted by CATV and the estimate for 1975 is 16 percent. On a nationwide scale, the penetration is over 25 percent. This is due to the strong demand for CATV in the rural areas. For the long term (i.e., in mid-1[illegible]), the penetration of CATV is expected to reach 75 percent. Table 2 shows the status of CATV system in 1972, in the major U.S. cities; Table 3 shows the forecasts for growth and penetration of CATV through 1985.* The above forecasts are based on the expected success of interactive pay TV, imported signals, and other special sources that can be provided once two-way transmission becomes available. The accuracy of these forecasts is contingent on continuation of favorable economic conditions and regulatory environment.

3. Alarm applications. A prerequisite for utilizing CATV for alarm systems is the availability of reverse transmission channels, so that the alarm signals can be transmitted from the subscriber to the alarm central station. The principle employed in CATV for alarm systems is very similar to the bridge-type systems offered by the telephone company (see Section C). In the CATV system, just as in a bridge-type telephone channel system, all alarm subscribers are generally connected to one common channel. The number of subscribers that can be served on a single channel is theoretically limited only by the Underwriters' Laboratories specifications, which require that every subscriber be sampled at

*These growth forecasts were developed during a previous SRI study conducted for the CATV industry.

SA-3755-2

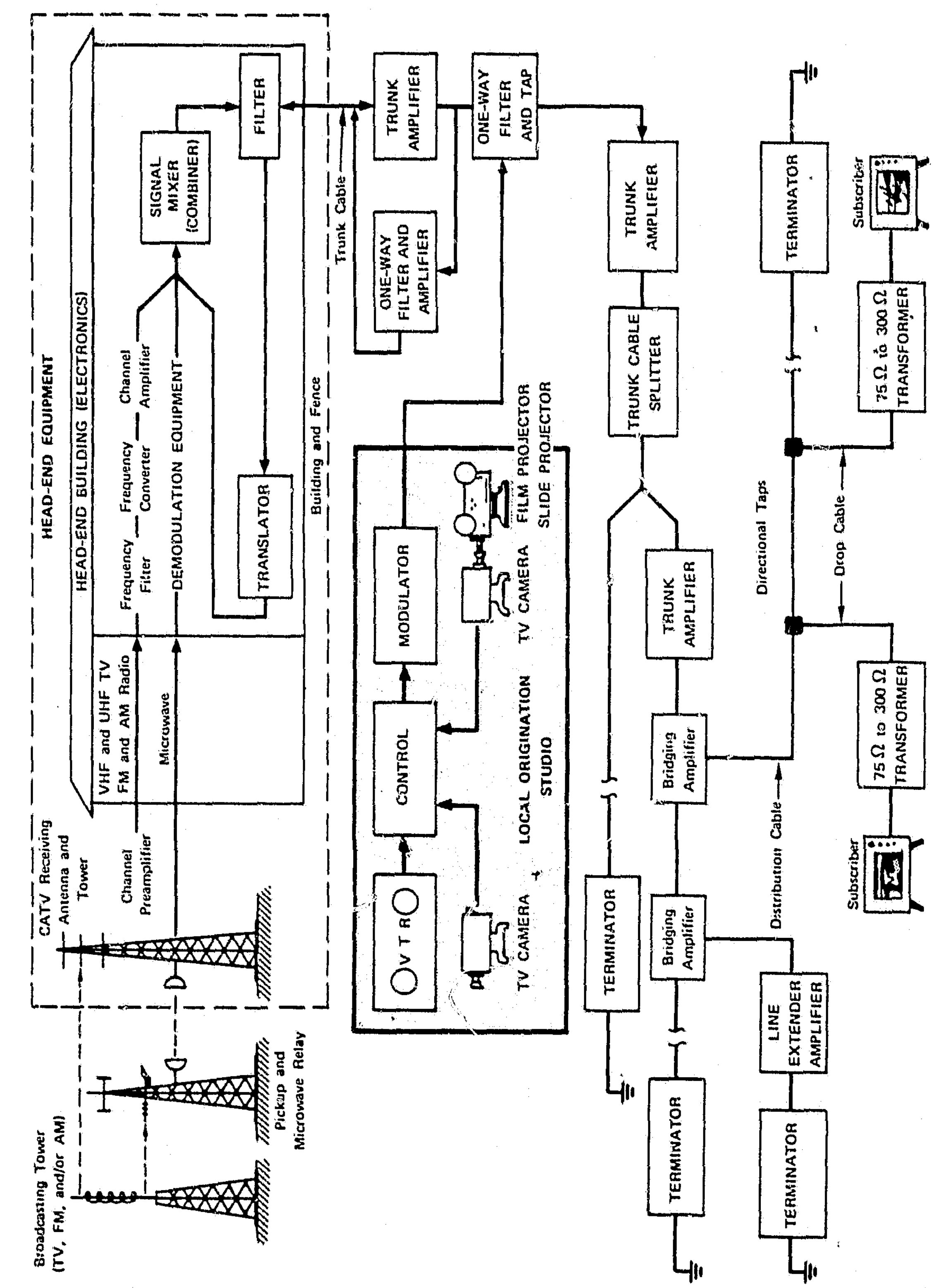

FIGURE 4 REPRESENTATIVE CATV SYSTEM

Table 2

CATV STATUS, BY HOUSEHOLDS, IN 153 CITIES WITH 100,000 OR MORE INHABITANTS: MID-1972
(in Millions)

CATV Activity	Households	
	Number	Percent
Fronted by CATV	1.9	10%
Franchised but not fronted by cable	5.3	28
Subtotal franchised	7.2	38%
Not franchised	11.8	62
Total	19.0	100%

Source: SRI

Table 3

GROWTH OF CATV: 1974-1977, 1982, 1985

	1974	1975	1976	1977	1982	1985
TV households (millions)	68.0	69.2	70.6	71.9	78.8	83.3
CATV households (millions)	9.0	10.5	12.3	14.4	27.6	36.3
CATV penetration (percent)	13%	15%	17%	20%	35%	44%
Homes with access to CATV* (millions (millions)	18.0	21.4	25.6	30.6	53.1	62.6
TV households with access to CATV (percent)	26%	31%	36%	43%	56%	75%

Note: All data are year-end figures.

*Homes with access to CATV are those that are passed by an existing cable distribution network.

Source: SRI

least once every 90 sec. In a normal telephone system, as described in Reference 8 and in Section C, the transmission speed is limited by the voice-band bandwidth of about 3 kHz as set by the telephone company. However, the CATV system offers ample bandwidth of the order of several megahertz; for example, it can be shown that as many as 50,000 terminals could be scanned in a polling mode once every second.

As with any polling scheme on a single channel, the major disadvantage is that accidental or deliberate injection of noise at any access point to the common-user channel could jam the system. One equipment manufacturer has proposed sectionalizing the system by installing switches at the trunk branching points. With this approach, the system would appear much like the proposed AT&T "closed-window" system,* where the access point to the bridge is operated by remote control. In the proposed CATV system, the switches at the branch points are also operated by remote control; with the only difference being that each CATV branch has about 100 households compared with only one for the telephone system. With this approach, the defective or jammed branch can be disconnected from the system until serviced. As a further outgrowth of the closed-window CATV system, each of the 100 homes on a branch could be assigned a separate frequency for signaling and supervision. In the latter approach, the alarm central station can open one branch at a time, observe all 100 channels simultaneously for the presence or absence of an alarm signal, and then move on to the next branch. The scanning of the system is extremely fast since no individual polling of subscribers is needed. The cost of this type of system is claimed to be very low, of the order of $20 per subscriber terminal when used in conjunction with a conventional set-top converter. Including the price of a set-top converter, it amounts to about $60 per subscriber. This

*See Section C, telephone.

type of systems approach has been successfully tested in Columbus, Ohio, with 1000 units in operation for a pay TV system. In the system a 16-bit message is continuously transmitted, indicating which channel is being observed. If this type of system finds general acceptance via pay TV, it would be easy to set aside a number of code combinations for the different types of alarms. These latest developments indicate that CATV has great potential for providing low-cost alarm circuits, provided that CATV becomes accessible to the majority of households and businesses.

4. Cost factors. For this study it was assumed that, for the near-term future, the only cost an alarm system operator might have to bear would be the installation of the necessary filters and amplifiers to implement the reverse transmission capability. For the long-term prospect, it is actually more likely that other interactive services will pay for the installation of the reverse transmission equipment. One likely vehicle for this occurrence is pay TV where the flat-fee subscription service would be replaced with a pay-as-you-watch approach, which requires a subscriber terminal and the reverse transmission capability.

For the cost analysis, it was assumed that the average system has a 1:4 ratio between trunk and distribution cables, with the trunk lines being 0.75-inch cables and the distribution lines being 0.4- or 0.5-inch coaxial cables. Accordingly, the trunk cable requires 3.5 amplifiers per mile versus 4 amplifiers for the distribution system. The costs per reverse transmission amplifier (and filters) are $200 for the trunk line and $164 for the distribution lines. A pro rata computation was made by calculating the conversion costs per mile of homes fronted. The equipment costs amounted to $831 per frontage mile plus an additional $312 for installation.

For this comparative analysis it was also assumed that a modem has to be installed at the subscriber's premises in addition to any alarm-generating device. The cost of $100 for the modem represents an average figure of the various approaches proposed by the CATV suppliers.

If the implementation of two-way CATV were entirely paid for by other than alarm services, then the additional monthly cost estimated for the alarm interfaces add-on should be about $3 per month in the case of 10 percent market penetration of the alarm systems, and about $1 per month for 100 percent penetration.

5. Regulation and policy

(a) General. The development of CATV is under the severe handicap of being subject to rules and regulations from all levels of government. At the highest level, fundamental decisions concerning copyrights and program limitations are being made by Congress or the Supreme Court. The Office of Telecommunications Policy (OTP), although it has no regulatory function, does investigate critical questions and makes recommendations to Congress as well as to the FCC. The basic rules for operation and technical specifications are devised by the FCC. Over the years, FCC rules have controlled the growth and economic well-being of CATV operations. Regulation is also provided by state public utilities commissions, which in some states have taken actions to control the composition and rate structure of CATV. In some states, CATV has been declared a public utility, but in others no action has been taken to control the medium. Local governments have the right to grant CATV franchises. Under this right, franchise fees are assessed and some free services to the city government may be part of the franchise agreement. In addition, cities reserve the right to control the rate structure and also may specify the technical performance beyond that specified by the FCC.

In addition to government bodies, CATV operators have to contend with numerous organizations such as the common carriers, the National Association of Broadcasters, and local interest groups.

(b) FCC rules and regulations. Two basic sets of rules promulgated by the FCC affect the operation of CATV: technical and political-operational.

The technical rules set minimum standards of performance. These standards prescribe picture quality as well as the minimum size of a system if operated in the top-100 market.

The political-operational rules specify the limitations for signal importation, program origination requirements, limitations on ownership, rules for pay TV, limitations on the type of program material shown, etc.

For the alarm industry, two rules are of prime importance:

(1) Systems built after March 31, 1972, must have a minimum capacity of 20 television channels in the forward direction and a plug-in capability* for two-way communication of non-voice channels.

(2) The above requirements apply also to systems built before March 31, 1972, and the conversion to plug-in, two-way capability must be completed by March 31, 1977.

The 1977 conversion date for all existing systems has been severely criticized by the industry. It has been claimed that it is economically unrealistic and would impose severe hardship on some systems operators. It is generally acknowledged in the CATV industry that the

*I.e., provision for connector plugs for reverse amplifier/filter modules.

1977 rule will be relaxed in order to ease the financial burden on the CATV operators. However, natural obsolescence makes it virtually certain that by 1985 all operating systems will have the two-way capability. It was stated earlier that in 1972 about 10 percent of the capacity was installed before the critical 1972 FCC deadline. However, even before the FCC ruling, several forward-looking larger systems operators purchased their systems with the add-on two-way capability. Thus, only a small percentage of the larger cities would come within the 1977 rule under which the conversion to two-way capability would involve major modification or perhaps replacement of the CATV system.

For systems built after 1972, implementation of 20-channel capacity and reverse-transmission capability represent only a nominal financial burden. For years, in expectation of two-way communications, the industry has supplied quality equipment with a minimum capacity of 20 channels; therefore, all major manufacturers implemented design modifications to provide two-way services. For such newer systems it may be relatively simple and not very costly to add the reverse-transmission capability; this is a feature of prime importance to the alarm industry if the use of CATV is to be considered.

6. Conclusions. The CATV medium appears one of the most promising for alarm signal transmission through the 1980s in those areas where widespread CATV coverage exists, particularly if two-way capability is implemented for other (non-alarm) applications. The degree of utilization of this medium depends on realization of its growth forecasts. (Best available forecasts are: 75 percent of households in the United States will be fronted by CATV in the mid-1980s). The actual growth of this medium and widespread implementation of the two-way capability will depend on economic viability, and only in lesser degree on FCC regulations.

E. Radio Frequency

1. Introduction. The radio frequency (RF) medium has the unique characteristic that it is within the public domain and is not under the administrative control of other parties. For alarm system operations this has the advantage that users of radio-frequency communications links do not have to depend on others to provide the basic transmission medium. However, the use of radio frequency is stringently regulated by the FCC and there is presently no FCC service category specifically assigned to large-scale security alarm signal transmission (although it is possible that such transmission could come under some existing subcategory).

2. Description of the medium. In contrast to other media, the radio-frequency medium is not constrained by the physical layout of wire or cable networks. This allows a measure of flexibility in alarm system design and implementation that is unique to this medium. However, the use of radio as a means of communicating non-verbal messages is not without its problems. Propagation conditions, such as skip, fading, ducting, and multipath, must be taken into account in the design and installation of transmission links. Moreover, radio receptions are subject to interference from transmitters operating in adjacent frequency bands (or ones that are harmonically related), to spurious radiations (e.g., electrical machinery, ignition noise, etc.), and to atmospheric disturbances. For these reasons, receiver design and choice of operating frequency are important if false alarms and/or missed messages are to be minimized. However, for alarm application, receiver performance (i.e., selectivity and sensitivity) is constrained by economic considerations and the choice of operating frequency is constrained by existing allocations of frequencies for other services.

The radio frequency medium has not been used extensively for security alarm systems because of the cost involved. Available radio equipment suitable for alarm transmission is designed primarily for licensed-service in special applications (e.g., police "stake-out," etc.). FCC rules prescribe an annual check and test of performance of licensed operation above 3 W, and this type of operation increases significantly the cost of a radio alarm system. A substantial part of this cost could be eliminated if a system were available that did not require licensed operation. At present non-licensed operation is only possible if the radio transmitters meet the requirements for "Low Power Communications Devices" (FCC Rules and Regulations, Vol. II, Part 15, Subpart E).

3. Alarm application. The results of the study showed that two simple RF communication netting configurations could satisfy the requirements of alarm signal transmission: single cell netting and multicell, or cellular netting. Single cell has the advantages of simplicity and of lower initial RF equipment costs compared with cellular netting. Cellular netting on the other hand appears to have the advantage of lower operating cost.

(a) Single-cell netting. Direct netting between the central station and the subscriber is generally known as the single-cell netting (i.e., the central station and subscriber units transmit the RF signals to each other directly, with repeater stations used only to relay the signal to and from blind spots). To minimize the number of repeater stations, the antennas of the central station must be located at a high elevation site overlooking the area to be covered (such as on top of a hill or tall building). This is to overcome signal attenuation due to physical obstructions in urban and suburban environments.

Typical communication components for a single-cell system include the following:

- Central station equipment, including antenna systems, a transceiver, and a modem for interfacing signals from communication equipment with the central station alarm equipment. The modem receives signals from the communication equipment and converts them into a form suitable for interfacing with the alarm equipment, e.g., frequency shift keying (FSK) a tone to a form suitable for processing (e.g., digital processing).
- Repeater stations, consisting of two transceivers and two antenna systems, one for transmitting and receiving signals to and from the blind spot areas and another to transmit/receive from the central station.
- Subscriber's RF equipment, including an FM transceiver connected to the alarm equipment via a modem.

With this netting method, the subscriber's RF equipment would be located within the subscriber's premises and the antenna would be placed on top of the roof or directly underneath it.

(b) Cellular netting. The cellular system divides the coverage area of a central station into small areas or cells. Within each cell is a local monitoring station that monitors all transmitters within its area. The local monitoring stations receive signals from subscribers and retransmit them to the alarm central station through leased telephone lines. For a polling system using the cellular netting configuration, the central station would use transmitters with sufficient power to cover all cells in the system. To overcome signal attenuation, as in the single-cell system, the central station antenna must also be located at a high elevation.

The communication components for subscribers and the central station would be the same as for a single cell system with the addition of local monitoring stations for each cell, leased telephone lines to a multiport bridge at the local telephone exchange, and a private line from the bridge to the alarm central station.

The results of the study indicated that the annual calibration of subscriber transmitters required by the FCC increases the operating costs of an RF alarm transmission system. This could be eliminated if the transmitter power were below 3 W.[10] Cellular netting would allow the subscriber's transmitter to operate at low output power because the distances would be relatively shorter (i.e., than a single cell).

The single cell netting configuration with transmitter output power in excess of 3 W was used in the cost analysis (Chapter 3) because of its simplicity and lower initial RF communication equipment investment cost.

4. Technical considerations

(a) Operating frequency and transmitter output power. In general, in short range communications (as for alarm signaling), RF equipment operating at a frequency between about 50 MHz to about 1000 MHz appears to be suitable. At frequencies below 50 MHz, RF interference becomes a problem; above 1000 MHz, a combination of factors including increased signal attenuation makes these frequencies unattractive.

The reliability requirements for alarm signal transmission and other major technical requirements for a RF transmission system were investigated in the study.[10] The most important requirement was found to be the transmitter power of subscriber equipment. It was found that to overcome transmission path losses and RF interference, transmitter power between 1 and 10 W would be adequate. This conclusion is based on a number of factors that were taken into account including: receiver performance (e.g., sensitivity), antenna characteristics and the expected transmission path losses (i.e., free space and obstructions), RF interference, and the required signal quality. However, at frequencies below about 500 MHz the transmission system analysis showed that the manmade RF interference becomes increasingly severe and that is then the major factor that determines the power requirements, rather than receiver sensitivity.

(b) Signal distortion and fluctuation. Physical obstructions in urban and metropolitan areas (buildings, etc.) cause multipath propagation, which affects the reliability of RF signal transmission by distorting the received signal and causing the received signal strength to fluctuate.

Signal distortion. The multipath effect distorts the received signal by superposition of signals traveling through different paths and arriving at the input of the receiver at different times (time-delay-spreading). Measurements conducted by SRI show that time-delay spreading of approximately 5 to 6 μsec can be expected in urban/suburban environments. Therefore, to take into account the signal distortion that can cause message errors, the transmitted signals should be spaced more than 6 μsec apart, i.e., signal bits should be transmitted 6 μsec or more after the preceding bit.

Signal fluctuation. Multipath propagation causes the received signal to fluctuate continuously or to fade because the motion of automobiles, aircraft, and other moving objects changes the signal paths. To meet the reliability requirements for alarm signal transmission under these conditions, frequency shift keying (FSK) or phase shift keying (PSK) modulation must be used for signaling. These techniques are less affected by signal fading than on/off keying (i.e., amplitude modulation). FSK

equipment is usually simpler and lower in cost than PSK equipment, and therefore it is more suitable for a low cost alarm system.

(c) Resistance to defeat. The RF system is susceptible to tampering by various methods. For example; it may be defeated by the following means:

- The electrical power into the building can be cut off.
- The antenna could be put out of operation by covering it with a large piece of metal (such as a large trash can), by short circuiting it to the ground, or by cutting the transmission line.
- The receiver could be jammed by RF radiation.

The resistance of the system to various forms of attack can be increased by the following means:

- Equipping the subscriber unit with a standby power supply.
- Placing subscriber antennas in an inaccessible location, e.g., high up on a roof top or under a roof.

There is no easy method to increase system resistance against jamming. The general practice used to resist jamming is to change the operating frequency, or to increase the transmitter power above the jamming power, but these methods are impractical.

5. Cost factors. The major cost of the RF communication medium is the initial cost of the subscriber's communication equipment and installation. The equipment cost is closely related to the quantity of production and the distribution method. The off-the-shelf price for a radio transceiver with an output power in the range of 1 to 10 W is between approximately

$100 and $2000* (depending on complexity, quantity produced, etc.). The price range of a modem for interfacing alarm equipment with RF equipment can be between $100 and $2000 or more depending on signaling rate. Development of subscriber equipment that combines transceiver and modem could reduce cost to the subscriber considerably. An optimistic estimate, based on mass production, and large quantity distribution and use, is $100 for an RF transceiver and a modem and about $15 for a subscriber antenna system (e.g., based on a monopole, ground-plane antenna, currently made in large quantities).

The labor cost for installing a subscriber unit is estimated on the basis of one half-day's work for each installation (i.e., about $80).† Four hours are estimated for the maintenance per subscriber unit per year.‡ The labor cost is estimated at $20 per hour.

The cost of central station communication equipment includes the cost of an antenna and a steel mast, two heavy-duty transceivers, a standby power supply, and a modem. The operating costs include the rent for an antenna site and a small building for housing the RF equipment and the monthly charge for electricity. Cost estimates for each item are $1000 for the antenna system, $1000 for the RF equipment and a standby power supply, $100 for the modem, $100 per month for the rent of an antenna site and small building, and $10 per month for the electricity. The operating costs for central station equipment also include the cost of

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*See Reference 10.

†This estimate includes transportation to and from the subscriber's premises, installation of the antenna and the RF equipment, and calibration of the transmitter power.

‡Assuming that a malfunctioning unit will be replaced with a rebuilt unit, and the cost of spare parts for rebuilding the subscriber's equipment is estimated as 5 percent of the total communication equipment cost per year per unit.

spare parts and maintenance (i.e., 5 percent of the equipment cost for spare parts).

6. Regulation and policy. An alarm transmission system using RF requires licensing by the Federal Communications Commission (i.e., unless it can meet the requirements for certain non-licensed categories set forth in FCC Rules and Regulations, Vol. II, Part 15, Subpart E). The FCC issues licenses, allocates and assigns frequencies, and regulates the operation of all radio stations. The results of this study show that these regulations* could greatly affect the design and operation of an RF alarm transmission system.

The FCC has allocated nine radio channels for radio alarm operation under Business Radio Service (Volume V, Part 91). Because it is expected that an alarm transmission system will employ digital transmission, the FCC Rules and Regulations regarding this type of transmission should be investigated with regard to the specific design and proposed implementation of any alarm transmission system using digital signaling. At present, FCC Rules and Regulations, Vol. V, Part 91, Subpart 91.113, require that a separation of 75 miles between any digital system and co-channel voice systems with station identification be made periodically by voice announcement.† Although the Business Radio Service represents the best possibility

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*FCC regulations pertinent to RF alarm signaling are those listed in FCC Rules and Regulations, Vol. II, Part 2, Frequency Allocations and Radio Treaty Matters; General Rules and Regulations, Vol. V, Part 89, Public Safety Radio Services, and Part 91, Industrial Radio Services.

†This is required by FCC Rule 91.152(a). However, if in the opinion of the FCC, alarm signaling can be categorized as telemetering (e.g., under the "Definitions," Part 91, Industrial Radio Service, FCC Rules and Regulations, Vol. V, exception from the requirements for station identification [91.152(a)] may be considered in specific instances (by FCC) on request.

for immediate channel access for radio alarm transmission, there are other possibilities for acquiring the needed channels and these possibilities were investigated in the study.[10] The major constraint is the problem of eligibility for entry into existing services. The service categories into which an alarm signal transmission system could gain entry are:

- Public safety service (Volume V, Part 89, FCC Rules and Regulations).
- UHF TV channels and reserve emergency pools in the 470-512 MHz band.
- Land mobile frequencies in 806 to 902 MHz band.
- Radio call box frequencies in 72 to 76 and 450 MHz bands assigned to local government service.
- Band from 1427 to 1435 MHz for telemetry and base station telecommand service with all operations secondary to federal government service.

7. Conclusions and recommendations. From a technical standpoint, the RF medium can be used for alarm signal transmission and can be designed to provide the required transmission reliability with reasonably high resistance to tampering. There are other factors, however, chiefly financial and regulatory, that would affect the selection of this medium for alarm signal transmission.

The operating cost of RF transmission systems is directly related to the costs of equipment, installation, and maintenance. The cost of RF equipment and modem is between \$100 and \$2000* or more each, depending on complexity, signaling rate, quantity produced, and so forth. The cost analysis of RF transmission systems shows that the cost of operating an RF transmission system is relatively higher than the other media investigated, although the current lower-bound costs of an RF transceiver and a modem were used in the analysis.

*Reference 11.

At present, the FCC has allocated nine radio channels for radio alarm operation under the category of Business Radio Service. Because it is expected that an alarm transmission system will employ digital transmission, the FCC Rules and Regulations regarding this type of transmission should be investigated with regard to the specific design and proposed implementation of any alarm transmission system using digital signaling.

Under the FCC requirements for Transmitter Measurements, an annual calibration of transmitters is required for transmitters with an output power in excess of 3 W. For operations with an output power below this level, this calibration is not required: consequently, the portion of the operating cost required for calibration is eliminated. Similarly, for operation under the Low Power Communication Devices category, the cost of an annual transmitter calibration is also avoided.

Operation of an alarm system using transmitters with an output power below 3 W, including those transmitters qualified for non-licensed operation, would require an additional evaluation to determine the transmission reliability for alarm signaling.

If it is feasible to operate RF alarm systems reliably using transmitters with an output power below the level requiring an annual calibration and that meet the relevant FCC requirements, further equipment development aimed at improvement in equipment reliability (i.e., long MTBF and cost reduction) may be warranted.

F. Other Transmission Media

In addition to the four major transmission media that were explored in depth in this study, additional media had been suggested from time to time for alarm signal transmission; some of these fall into the "unusual" or "exotic" category. These media include the following:

- Lasers, both optical and infrared
- Microwave (radio frequencies above 1 GHz)
- Optic fibers
- Water lines (using pressure transducers).

The analysis of these communications techniques consisted primarily of a review of previous SRI communications studies,[12,13] and a cursory review of possible recent advances in the state of the art. It was concluded that, while the first three of the media listed above offer very wide bandwidth (and data rate) capability, the bandwidth requirements for alarm signal transmission are very modest and can be easily satisfied by more conventional means. Furthermore, laser and, to some extent, microwave links operating in the lower atmosphere would be susceptible to interruption by birds, smoke, fog, rain, and snow. Moreover, the first three media cannot compete in the foreseeable future in terms of cost with telephone lines, CATV, or radio (below 1 GHz). The feasibility of transmission of signal by pressure changes in water lines was briefly analyzed in Reference 12. It was concluded that this technique is impractical.

Recent press releases have indicated that some cities (e.g., Detroit) are currently experimenting with burglar alarms actuating strobe lights on the roofs of major buildings; flashing strobe lights indicate a "burglary in progress" status to airborne police helicopter patrols. SRI did not evaluate the cost-effectiveness of this method. However, previous studies for the U.S. armed forces and police departments have indicated that the operational cost of continuous airborne patrolling is very high. Use of

other types of possible receiving platforms, such as tall buildings, hilltops, etc., was not investigated.

In conclusion, SRI was unable to identify any additional transmission media, other than the four media treated in depth in this study, that offer a hope of becoming practical and low-cost alternatives for transmission of alarm signals in the foreseeable future.

CHAPTER 3. COMPARATIVE EVALUATION

A. Introduction

The characterization of each transmission medium given in Chapter 2 provides a basis for the comparison of the media for the intended application. The primary objective of the evaluation was to delineate the relative advantages and disadvantages of each medium and the individual systems that are, or could be, used in conjunction with a particular medium. To perform a comparative evaluation, it is first necessary to:

- Identify, specifically, the alternative media/systems that are to be compared.
- Identify those parameters that (a) form a common ground for comparison and (b) have relatively high relevance to future decisions regarding which media/system are best suited for various types of alarm and response systems.

B. Media Selected for Comparative Evaluation

Of the four media considered in the study, power lines were eliminated from further consideration for the reasons given in Chapter 2. The remaining three, telephone and CATV networks and the radio medium, were considered to be potentially viable alternatives for alarm transmission and were subjected to comparative evaluation. The following specific media/systems were considered in the evaluation as candidates for current, near-term, or long-term alarm systems.

Transmission Medium	System
• Telephone network	Series loop system (e.g., McCulloh loop)
	Direct connection*
	Multiport bridge*--one subscriber per port
	Multiport bridge*--ten subscribers per port (nodule concept)
	Auto-dialer, subscriber owned
	Auto-dialer, leased from a telephone company
• Cable television network	Radio frequency carrier (using two-way transmission)
• Radio	Single-cell, two-way, frequency-shift keying

C. Technical Requirements and Media Capability

The comparative evaluation was predicated on the capability of the transmission medium to meet certain technical requirements that are derived from the operational needs of the security system and that are independent of the medium. The primary parameters that quantify these requirements are the following:

- The data rate capacity of the medium, which is directly related to the available bandwidth.
- The probability of false alarm, or undetected true alarms, both of which are related to the signal-to-noise (S/N) ratio. The desired S/N ratio in turn determines the signal power requirements. It should be noted that only the transmission-medium-generated false alarms have been considered; false alarms caused by human error are outside the scope of the study.*

*Suitable, or modified, to use voice/data grade telephone channel (3002 series).

1. Required data rates. After an extensive review of a wide spectrum of alarm signaling concepts,[14] SRI selected two as prime candidates for the alarm signal transmission application:

(a) Alarm reporting with periodic self-reporting of status; a low-cost alternative, requiring only one-way transmission.

(b) Direct sequential polling with verification, in which polling scan is interrupted when an alarm message is received; the subscriber station is then reinterrogated. This scheme was selected as a high-reliability, resistant-to-tampering, alternative since it provides continuous line supervision.

Clearly, the latter concept (b) requires a higher data rate capability than the former; also, it is more prone to transmission-medium-generated false alarms due to the high traffic volume resulting from continuous polling of subscribers. For these reasons, direct sequential polling (with or without verification) was selected for the evaluation of the traffic rate requirements.

The Underwriters' Laboratories requirements for Grade A and B approval for alarm systems state that:

- The size of the UL approved alarm systems must not exceed 1000 subscribers per central station.
- The time lapse between the occurrence of a status change and the recording of that change at the central station cannot exceed 90 sec.

*The human-error-caused false alarms represent, perhaps, the single major obstacle to wide-spread acceptance and implementation of burglar alarms. This problem is still awaiting a solution.

Supporting analyses conducted by SRI[14,15] have shown that the above UL requirements can be satisfied for 1000 subscribers per system with data rates as low as, perhaps, 240 bits/sec. The candidate transmission media exceed these modest data rate requirements by at least one order of magnitude. For example, the data rate capacity of the telephone 3002 voice-grade lines (unloaded) is at least 2400 bits/sec. Even higher data rates can be supported by the CATV medium.

2. Media-generated false alarms. As in the evaluation of data rate requirements, polling systems with 1000 subscribers were used in the analysis of media-generated false alarms. Two types of errors have been evaluated:[15]

- False alarms (i.e., type 1 errors)
- Undetected true alarms (type 2 error).

The expected frequency of both of these types of errors can be determined on the basis of the single-bit error rates for each of the candidate media. The single-bit error rates for the telephone medium, quoted by the telephone company, may range from 10^{-5} (on the average, one bit in error out of every 100,000) to the worst case of 10^{-3}* (one error bit in every 1000). Error rates of this magnitude or less can be achieved by the radio medium and especially the CATV medium.

Reference 15 shows that even for the worst-case bit error rate (10^{-3}), very low medium-generated false alarm rates (of the order of one in every few years) can be achieved even for polling systems containing up to 1000 subscribers through the implementation of such features as (1) a requirement of two consecutive alarm messages (or a verification message) before an alarm report can be generated, and (2) use of additional bits in the

*For long-distance transmission, involving several microwave links.

status message for error detection. These achievable, low, medium-generated false alarm rates are many orders of magnitude below those caused by human error, as is demonstrated by the experience of central station operators and police departments.[16,17]

Non-detection of true alarms (type-2 errors) has been shown[15] to be even less frequent; a true alarm going undetected is expected to occur once in a period well exceeding the lifetime of the equipment.

3. Conclusions. The capability of the transmission media subjected to comparative evaluation, in terms of data rate capacity and expected error rate, exceeds by a wide margin the rather modest requirements imposed by alarm signal traffic. Since the telephone, cable television, and radio media appear to be in no way constrained for alarm signaling applications by the available data rates or the error rates, these two parameters were omitted in the comparative evaluation of the transmission media.

D. Parameters Used in the Comparative Evaluation

A relatively large number of transmission system parameters were considered in the study. The parameters that evolved as being the most important, from the standpoint of a comparative evaluation, are listed below:*

- Technical requirements
- Status of candidate systems (state of the art)
- Dependence on other services
- Availability
- Expansion potential
- Reliability, including resistance to tampering

*Interface constraints were not considered as a separate evaluation parameter because in most cases (except for the non-telco dialer) the interface requirements are similar. When such requirements are different (i.e., non-telco dialer), they are reflected in the system cost.

• Regulatory and policy constraints
• Cost.

It was found that all of the potentially viable media/systems could perform in a satisfactory manner to meet the purely technical requirements such as traffic and error rates, range, and similar communications-related parameters. Conversely, cost was found to be the single parameter that varies to the greatest extent depending on which of the media/systems are being compared. For this reason costs for the principal candidate media/systems were analyzed in depth.

Section E, following, presents the method and results of the technical comparative evaluation; Section F presents the method and results of the cost comparison.

E. Evaluation of Technical and Other Non-Cost Parameters

1. Method. In the comparative evaluation emphasis was placed on practical utility (and cost) because of the intended application of external alarm transmission to low- and middle-income population areas. While every effort was made to indicate the relative significance of the transmission system parameters, no numerical weighting coefficients were used and no overall numerical scores were computed for the competing transmission media systems. In studies of this type there is the temptation to quantify all relevant parameters on a common scale to form a basis for overall numerical scoring. SRI did not use this approach because many of the system parameters either simply cannot be quantified or may be subject to unexpected changes (e.g., in policy or regulations), or their importance may vary under different circumstances. Instead, SRI compared the transmission media/systems on the basis of each system parameter individually and indicated: (a) the relative significance of each parameter and (b) how this significance may change under some circumstances (e.g., sensitivity to factors such as population density, penetration levels for alarm systems, etc.).

In many instances, we found it impractical to compare media/systems on any basis other than the collective best judgment of a panel of experts which included, but was not limited to, the study team members. In this regard, the method selected for approaching the problem of comparative evaluation was a simplified version of the Delphi method developed by O. Helmer of the RAND Corporation.* In brief, the Delphi approach uses the following sequential questioning process:

• A series of questions about a particular problem is asked independently of each member of an expert group.
• Responses are analyzed and a summary of the consensus is prepared.
• Each person questioned is given his original answers and the consensus report and asked if he wishes to change any responses in light of the consensus.
• Each respondent is asked to explain any of his answers that differ significantly from the consensus, identifying particularly any special knowledge available only to him.

2. Results. Table 4 presents the results of the comparative evaluation for the candidate media/systems. Corresponding results are shown in Table 4 for the cross-town power lines medium solely to emphasize the reasons for its elimination.

The evaluation parameters shown in Table 4 are defined as follows:

• Status--Degree of readiness or availability of hardware and components; state of the art.
• Availability to subscribers--Degree of likelihood--in 1975 and in mid-1980s--that a potential subscriber selected at random from the entire country could avail himself of the alarm service using the particular medium/system.

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*A structured method of evaluation using consensus of opinions of experts.[1a]

CONTINUED

1 OF 2

- Regulatory and policy constraints
- Cost.

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*A structured method of evaluation using consensus of opinions of experts.[18]

- Expansion (growth) potential--Potential for a massive expansion of the use of the given medium/system, given that some level of deployment (utilization) of the system has already been achieved (i.e., potential for making the system available to nearly everybody).
- Systems and equipment reliability--Reliability of hardware, including media limitations (e.g., RF noise for the radio medium), in terms of (a) reliable signal transmission, (b) expected mean time between failure (MTBF).
- Maintainability--Ease of maintenance, including consideration of where the responsibility for maintenance rests (e.g., with telephone company vs the alarm company).
- Resistance to tampering--Susceptibility to jamming, physical tampering with media components, and "clever schemes" for disabling the system, such as via saturation (e.g., tying-up of auto-dialer phone line).
- Regulatory and policy constraints--Pertinent regulations by Federal Communications Commission and other government bodies that may apply, especially for RF and CATV transmission; also attitudes and policies of utility companies vis-a-vis alarm signal transmission, etc.

F. Evaluation of Costs

The objective of the cost analysis performed during the study was to compare alternative media resource requirements using a common set of ground rules and uniform estimating techniques. It should be emphasized that the costs presented in this analysis are for comparison purposes only, although current media lease rates and actual expenses were used in the calculations whenever they were available.

Preliminary to performing the cost analyses for the transmission systems under consideration, the important hardware components for each system had to be identified, together with relevant non-hardware cost elements, such as maintenance, spares, and return on investment. Figure 5 shows the major hardware elements for each system, along with a delineation of those components that have been included as a part of the transmission medium and evaluated in terms of cost.

Table 4

COMPARISON OF MEDIA SYSTEMS

Media/Systems	Status	Dependence on Other Services	Availability (to subscribers) Present (1975)	Potential (mid-1980s)	Expansion (growth) Potential	Reliability Systems and Equipment	Maintainability	Resistance to Tampering[■]	Regulatory and Policy Constraints	Comments
Telephone										
Direct connect	Off-the-shelf	Telephone companies	Available	dc: unlikely in most areas	Limited by wire plant	Good	Good	Very good	Telephone companies not obligated to provide metallic continuity channels	
Series loop	Off-the-shelf	Telephone companies	Available	dc: unlikely in most areas	Limited by wire plant	Good	Good	Good	Telephone companies not obligated to provide metallic continuity channels	
Multiport bridge	Off-the-shelf; improved system in development	Telephone companies	Limited equipment availability	Nearly universal	Excellent	Good	Good	Good to very good	—	"Open window" bridges available today. "Closed window" bridge (high resistance to defeat) available last quarter, 1976
Auto-dialer	Some off-the-shelf	Telephone companies	Limited equipment availability	100% of telephone subscribers	Excellent	Poor to fair (improvement possible)	Good	Poor (improvement possible)	Some larger cities have outlawed use of auto-dialers to police	Needed improvements include self-checking and antitamper
CATV (Two-way)	Equipment available	1. TV subscription 2. Two-way: interactive services	Limited to specific locations	70%*	Linked to CATV growth	Good	Good	Good	Deregulation of FCC rules for two-way capability under consideration (see FCC R&R, Vol. III, Parts 76 and 78)	1. Availability of CATV medium highly dependent on future proliferation of TV service 2. Two-way capability for services other than alarm depends on future demand for interactive services
Radio	Some off-the-shelf	Usually none	Limited equipment availability	85%†	Limited by availability of RF spectrum	Fair to good	Good	Good	If commercially operated—under FCC R&R, Vol. V, Part 91. If public service operated—under FCC R&R, Vol. V, Part 89. For other rules, see FCC Vol II, Part 2.	Presently expensive; terrain/range limited. The only transmission medium within the public domain and not under the administrative control of other parties
Power lines§	Limited testing (for remote meter reading)	1. Electric power 2. Remote meter reading	None	Very unlikely	—	Poor	Unknown‡	Potentially very good	Medium unlikely to be available due to policy position of electric utilities	Poor reliability. Reevaluation may be warranted if remote meter reading via power-line carrier is introduced.

*Based on recent market predictions for CATV service.
†Some locations inaccessible by radio for terrain or other reasons.
‡Requires maintenance by high-voltage-certified utility personnel.
§Results given here solely to emphasize the reasons for elimination of the medium.
■See Reference 19.

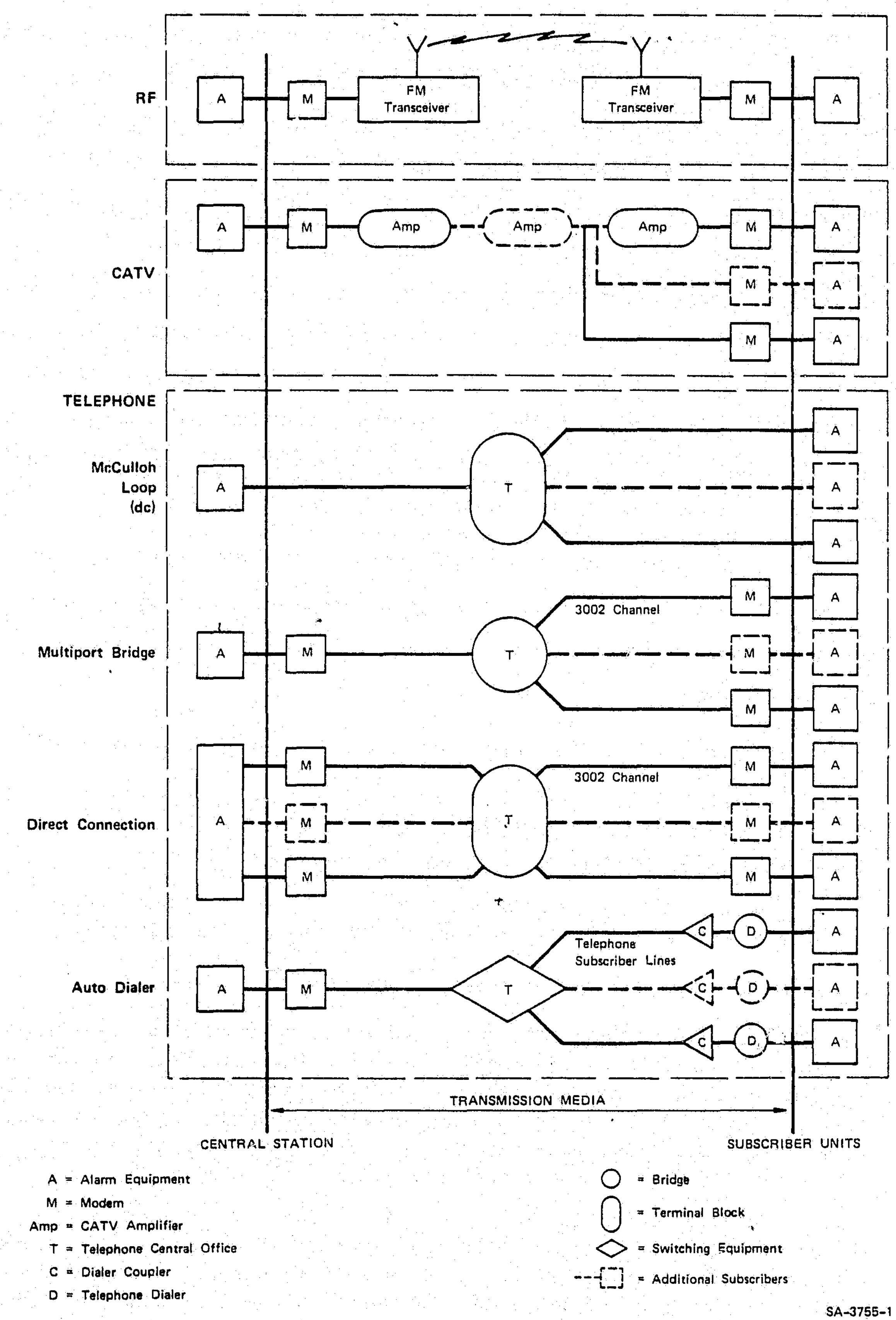


FIGURE 5 BASIC COMPONENTS OF TRANSMISSION MEDIA

1. Method and assumptions. The analysis included the estimation of costs for current, near-term and long-term systems. Current systems are those burglar alarm communication methods currently in use by the alarm industry and others. Near-term systems are technologically feasible systems that are not now in widespread use but that could be implemented within the next five years. Long-term systems are those that are technologically feasible but that are not expected to be implemented before the early 1980s (10 to 15 years hence). An equivalent monthly cost for these current and future systems was computed by dividing the initial investment required for materials, equipment, and system installation by 120 months (ten years of operation) and then adding monthly maintenance, equipment lease expenses, and operating profit.

In preparing the estimates, uniformity in the handling of the data was emphasized to provide media costs that accurately represent the relative differences between systems. Major assumptions made in the analysis were the following:

- A uniform subscriber and central station modem costs of $100 per unit.
- A 10 percent market penetration estimate.*
- Equivalent 1975 dollars to cost all systems.
- A computed large city population density of 2000 households per square mile (average for the 20 largest U.S. cities).†

*I.e., 10 percent of households are assumed to subscribe to the alarm service. Other penetration levels were also investigated; however, except in the case of the CATV and the radio transmission media, the alarm transmission costs were found to be largely independent of the penetration level. Sensitivity of costs of the CATV and the radio systems to penetration levels are discussed in Section 2(b) below.

†Other population densities (i.e., those typical for a suburban town, an isolated small town, and rural areas) were also considered. The results indicated that average telephone loop distances vary little between metropolitan, suburban, and rural areas (between 0.9 and 1.1 miles was average).

- A 10-year operating life for all systems.
- A 15 percent compound-interest return on initial investment in materials, equipment, and installation expenses.* This return on investment applies if this investment is made by the alarm companies or some other part of the private sector (e.g., through lease backs). However, a lower rate of return may apply if the funding for the initial investment is obtained from other sources, such as government loan or subsidy, or a direct purchase by an individual. This is discussed further in Section 2, below.
- For the CATV medium.

  For the current and near-term future, it was assumed that the total cost of reverse amplifiers and filters must be borne by the alarm service subscribers; for the far-term future it was assumed that two-way communication capability is in place and its costs are sunk. It was further assumed that alarm system subscribers already subscribe to the standard TV reception service.
- For the radio medium

  Present } Off-the-shelf hardware
  Near-term }

  Long-term

  Long-term--Relaxation of FCC requirement for annual frequency and power checks and a doubling of the expected MTBF.
- For the telephone medium

  - Dedicated systems

    Present--Current tariff rates for alarm applications.

    Near-term--Current tariffs for digital data transmission.

    Long-term--Doubling of the current tariffs for alarm service. (Based on statements made by AT&T personnel regarding the true costs of line installations and maintenance.)

*Under certain assumptions, explained in Reference 11, this interest rate translates to a higher rate.

- Switched systems

Auto-dialers are assumed to operate over the subscriber's regular telephone line, a service that is paid for elsewhere. Currently, monthly rental costs of $5 have been assumed for dialers supplied by the telephone companies. For privately owned (non-telephone company) dialers, an additional monthly lease cost of $5.50 was assumed for a coupler, as required by the telephone company.* No such devices are required for telephone-company supplied dialers.

2. Results

(a) Equivalent monthly costs. The results of the cost estimating procedure are shown in Tables 5, 6, and 7. The basis for these costs are included in Technical Note SDD-TN-118, which shows the conversion of costs per strand mile for CATV, costs per square mile (radio), and total telephone system costs per household to alarm communications costs per month per household. Figures 6, 7, and 8 provide a graphical representation of the data included in Tables 5, 6, and 7.

As shown in Tables 5 through 7, the monthly expenses are divided into three major categories:

Initial investment

- The cost of subscriber modem and interface equipment.
- The prorated (per subscriber) portion of the central station modem.
- Other material costs.
- Installation.

All of the above require capital outlay at the beginning of operation.

*As mentioned earlier, a recent interim ruling (currently disputed in court), by the California Public Utilities Commission, eliminated this requirement in that state.

Table 5

ESTIMATED COSTS PER MONTH--CURRENT
(10% Penetration Level--1975 Dollars)

Cost Element	McCulloh Loop (dc)	Direct Wire	Multiport Bridge	Multiport Bridge with Nodule	Non-Telco Dialer	Telco Leased Dialer	CATV	Radio
Investment								
Materials and equipment				Near-Term System			Near-Term System	
Central station modem		$ 0.83	$0.01		--	--		$ 0.02
Subscribers modem		0.83	0.83		--	--		0.83
Line costs	$0.17	--			--	--		--
Interface equipment (Other)	--	--	0.01		$ 1.19	$0.34		1.05
Installation costs								
Line		0.17	0.17		--	--		--
Equipment	--	--			0.25	0.26		0.67
Operations								
System maintenance		2.50	1.67		0.83	0.42		6.67
Maintenance spares	--	--	--		0.27	0.27		0.10
Utilities and miscellaneous	--	--	--		--	--		0.37
Remote site rental (repeater)	--	--	--					0.50
Media lease expenses	3.50	3.50	3.69		5.50	5.00		--
Return on Investment	0.52	5.57	3.13		4.39	1.83		7.82
Total monthly costs	$4.19	$13.40	$9.51	--	$12.43	$8.12	--	$18.03

Table 6

ESTIMATED COSTS PER MONTH--NEAR TERM
(10% Penetration Level--1975 Dollars)

Cost Element	McCulloh Loop (dc)	Direct Wire	Multiport Bridge	Multiport Bridge with Nodulè	Non-Telco Dialer	Telco Leased Dialer	CATV	Radio
Investment					Same as Current System Costs*	Same as Current System Costs		Same as Current System Costs
Materials and equipment								
Central station modem		$ 0.83	$ 0.01	$0.01			$0.06	
Subscribers modem		0.83	0.83	0.08			0.83	
Line costs	--	--	--	0.08			0.53	
Interface equipment (Other)	--	--	0.01	0.01				
Installation costs								
Line	$0.17	0.17	0.17	0.84			0.20	
Equipment	--						0.04	
Operations								
System maintenance		2.50	1.67	0.50			0.17	
Maintenance spares	--	--	--				0.07	
Utilities and miscellaneous	--						0.28	
Remote site rental (repeater)	--							
Media lease expenses	5.00	5.00	5.23	0.73				
Return on Investment	0.52	5.57	3.13	3.13			5.06	
Total monthly costs	$5.69	$14.90	$11.05	$5.38	$12.43	$8.12	$7.24	$18.88

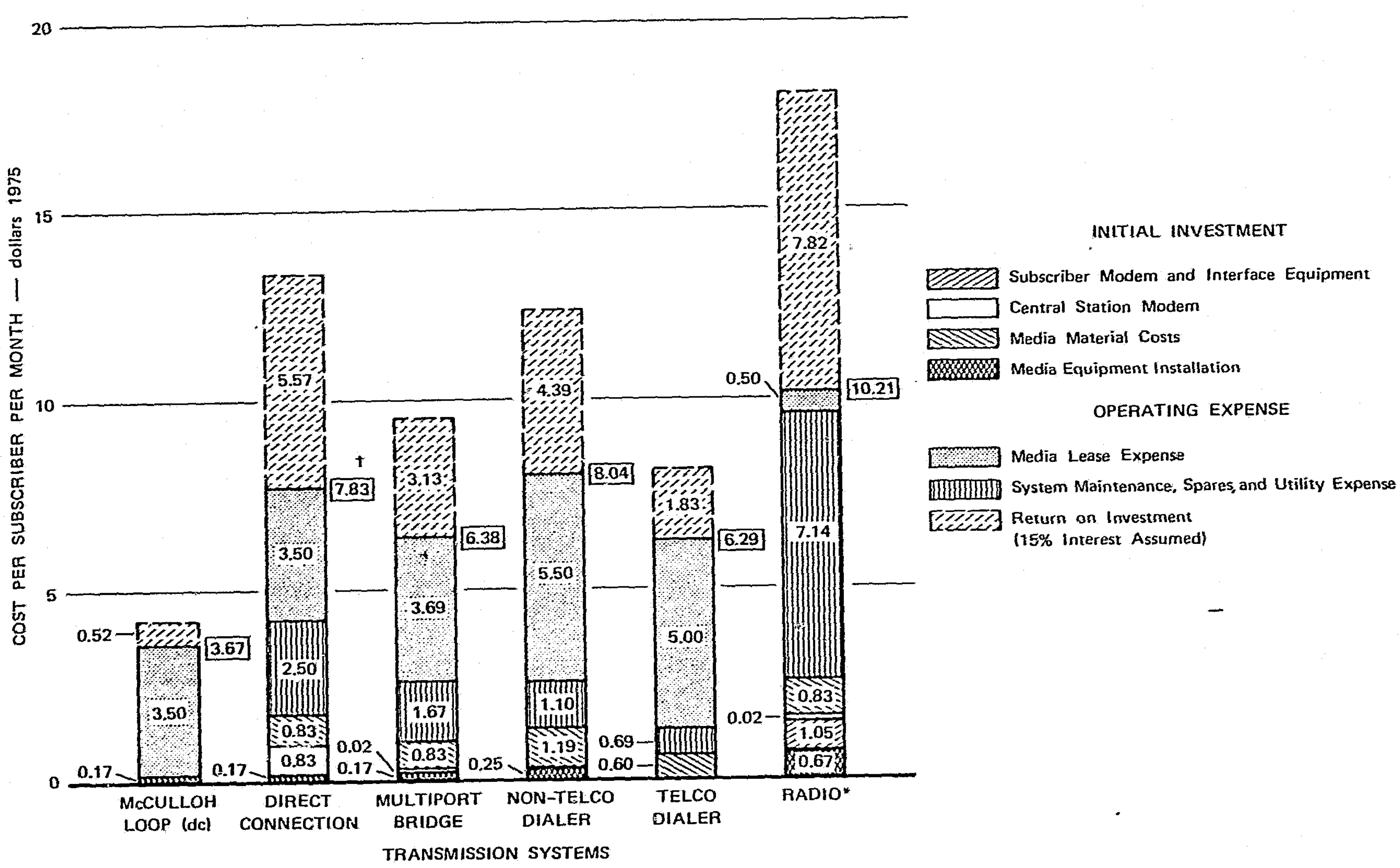
*Should the requirement for the interface equipment for non-telco dialers be eliminated, the costs would be reduced by the monthly coupler rental cost of $5.50 (under Media Lease Expenses), to a new total of $6.93.

Table 7

ESTIMATED COSTS PER MONTH--LONG TERM
(10% Penetration Level--1975 Dollars)

Cost Element	McCulloh Loop (dc)	Direct Wire	Multiport Bridge	Multiport Bridge with Nodule	Non-Telco Dialer	Telco Leased Dialer	CATV	Radio
Investment					Same as Current System Costs*	Same as Current System Costs		
Materials and Equipment								
Central station modem		$ 0.83	$ 0.01	$0.01			$0.06	$0.01
Subscribers modem		0.83	0.83	0.08			0.83	0.42
Line costs	--	--	--	0.08			--	--
Interface equipment (Other)	--	--	0.01	0.01			--	0.52
Installation costs								
Line	$0.17	0.17	0.17	0.84			--	--
Equipment	--	--					0.04	0.67
Operations								
System maintenance		2.50	1.67	0.50			0.17	1.67
Maintenance spares	--	--	--	--			0.07	0.08
Utilities and miscellaneous	--	--	--	--			0.28	0.37
Remote site rental (repeater)	--	--	--	--				0.50
Media lease expenses	7.00	7.00	7.30	1.00			--	--
Return on Investment	0.52	5.57	3.13	3.13			2.83	4.93
Total monthly costs	$7.69	$16.90	$13.12	$5.65	$12.43	$8.12	$4.28	$9.17

*Should the requirement for the interface equipment for non-telco dialers be eliminated, the costs would be reduced by the monthly coupler rental cost of $5.50 (under Media Lease Expenses), to a new total of $6.93.



*Basic assumption: Ten percent of households in an area will subscribe to alarm service.
†This cost is independent of lease line length if wholly within a telephone base rate area.

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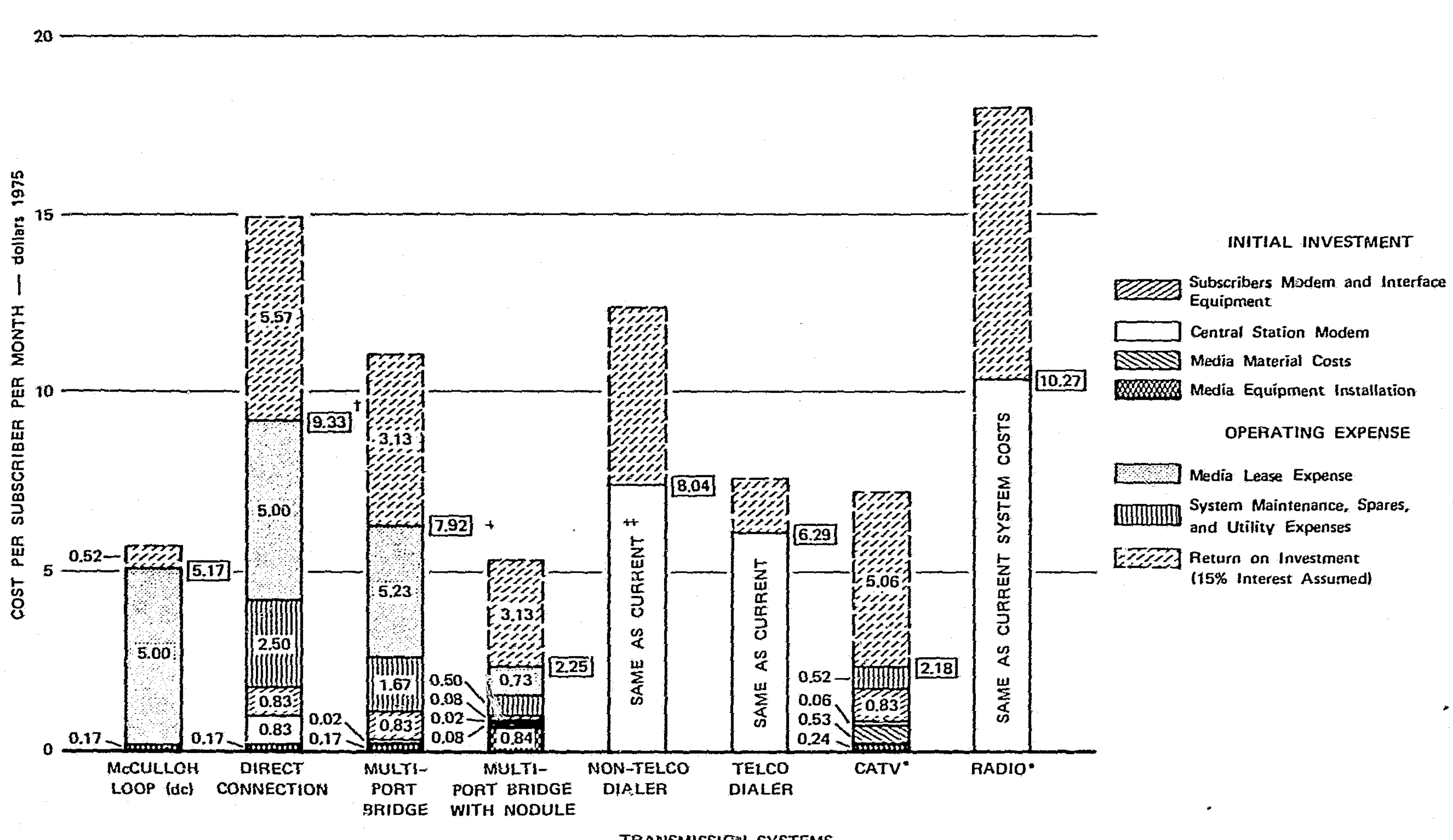
FIGURE 6 ALARM TRANSMISSION SYSTEMS COSTS PER SUBSCRIBER PER MONTH–CURRENT



*Basic assumption: Ten percent of households in an area will subscribe to alarm service.
†This cost is independent of lease line length if wholly within a telephone base rate area.
‡Should the requirement for the interface equipment for non-telco dialers be eliminated, the costs would be reduced b,· the monthly coupler rental cost of $5.50.

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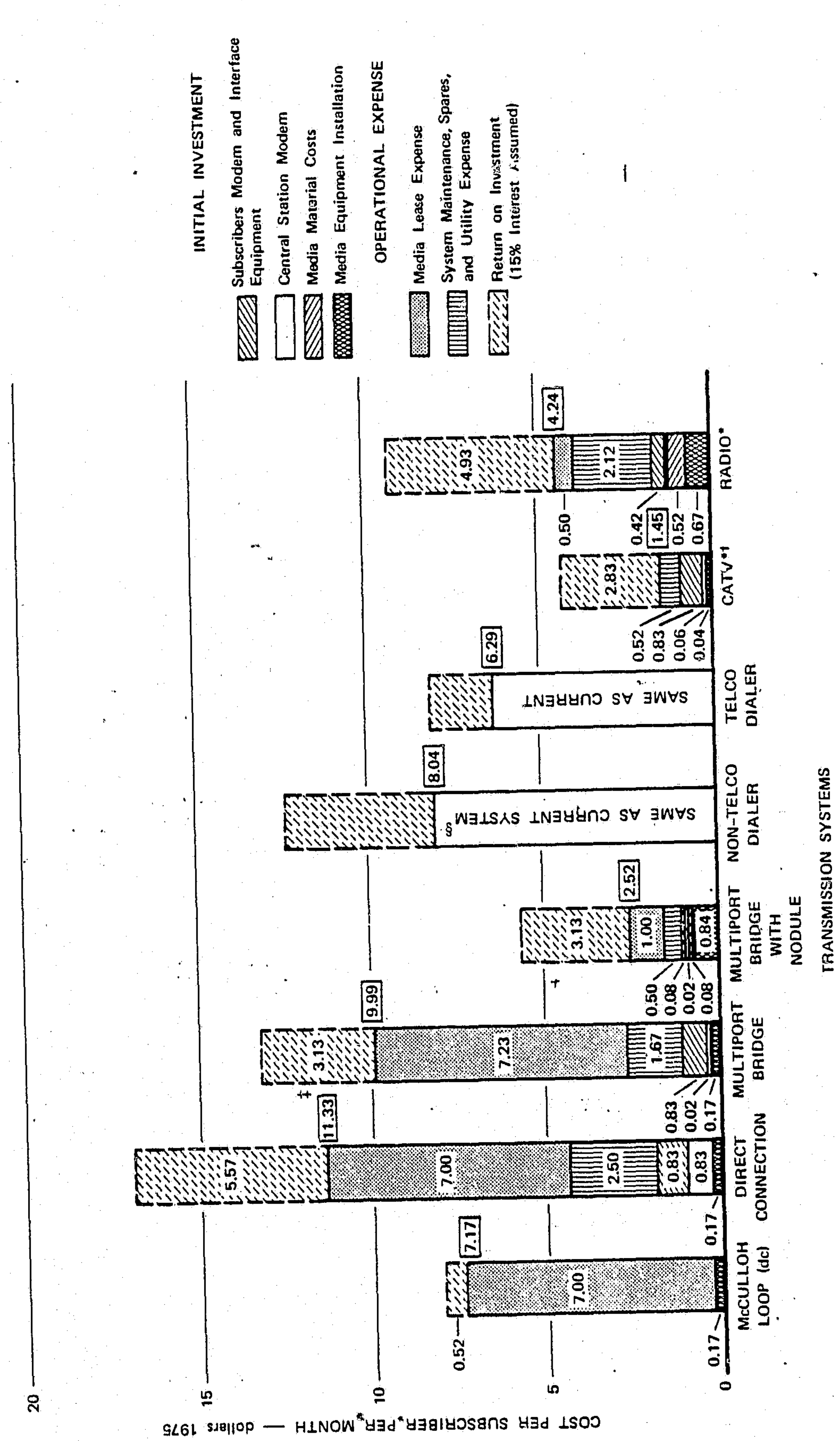
FIGURE 7 ALARM TRANSMISSION SYSTEMS COSTS PER SUBSCRIBER PER MONTH–NEAR-TERM



*Basic assumption: Ten percent of households in an area will subscribe to alarm service.
†Assumes reverse transmission filters and amplifiers are in place.
‡This cost is independent of lease line length if wholly within a telephone base rate area.
§Should the requirement for the interface equipment for non-telco dialers be eliminated, the costs would be reduced by the monthly coupler rental cost of $5.50.

FIGURE 8 ALARM TRANSMISSION SYSTEMS COSTS PER SUBSCRIBER PER MONTH–LONG-TERM

Other expense (not requiring an initial capital outlay)

- Monthly lease costs of lines and equipment
- Maintenance, spares, and utility expense.

Return on investment. Directly proportional to initial investment cost. Based on a 15 percent compounded rate of return on the initial investment. The corresponding segments of Figures 6 through 8 are dashed since this rate of return may apply primarily in the case if initial-investment funds are provided by the alarm companies or some other part of the private sector, and alarm service is provided to subscribers on a monthly-cost basis. Should the funds for the initial investment be provided instead, in the form of a government loan or subsidy, lower rates of return may apply. Finally, under some circumstances, it may be possible for the individual subscribers to purchase that portion of the equipment that is located on their own premises. Even in this case, the true cost will include a certain amount allocated to return on investment, because subscribers must either borrow the money for capital investment (and pay interest), or forego the return (interest) on the amount of initial investment. In the latter case, the rate of return on investment (i.e., the cost to subscriber of tying-up his capital) should be adjusted to that which the individual can realistically earn on his personal capital. The option of purchasing alarm transmission equipment by subscribers is realistically available only for telephone auto-dialers.*

It should be pointed out that the exact rate of return on investment that may apply under the various conditions is of secondary importance in the comparative evaluation of the transmission media/systems.

As shown in Figures 6 through 8, telephone related systems (dc series loop, direct wire, and multiport bridge) are expected to increase in costs as telephone utility companies are allowed to increase their

*Even for radio systems, it is unlikely that a response agency would permit, for operational reasons, ownership and maintenance of the subscribers' transceivers by the subscribers.

rates to levels which match current line installation and maintenance costs. The current telephone tariffs for alarm service (dedicated wire pair and series loop) have been low. The telephone companies have been charging their customers on the basis of the class of utilization of the medium, such as alarm service, telegraph/telemetry, voice and digital data transmission, with the last class commanding the highest tariffs. As indicated, monthly line lease expenses for alarm signal transmission could be increased to match current tariffs for digital data transmission service by 1980 (because both use voice grade channels) and could double* the current costs within 10 to 15 years.

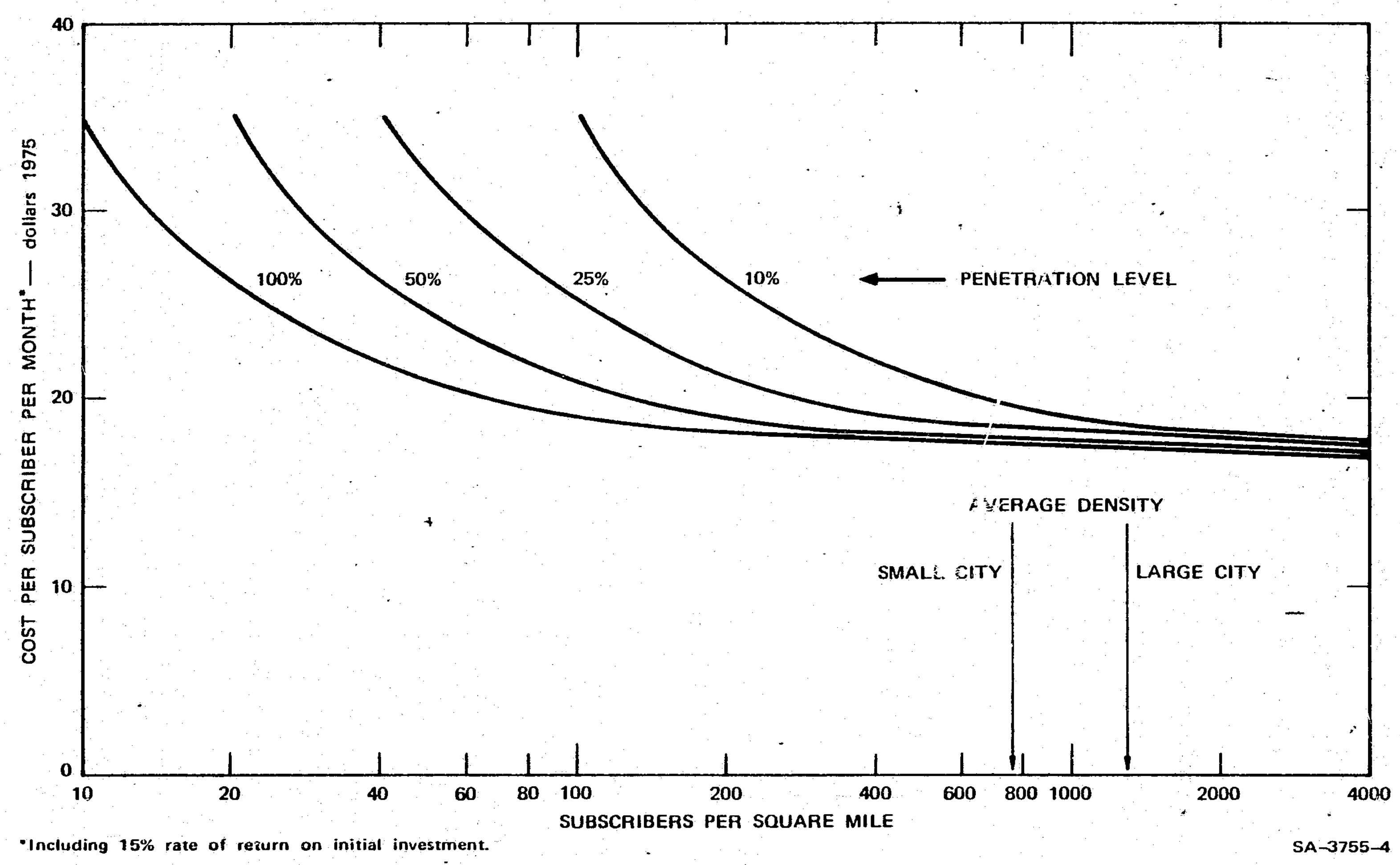
As shown in Figure 6 dc series loop systems are currently the lowest-cost communications media used in reporting burglar alarms. However, due to preferential telephone utility company rates, the automatic dialers and the multiport bridge systems (typified by the Larse system) are also very low cost. If these preferential rates are to match the tariffs for digital data transmission over the next five years, monthly rates will be increased to those shown in Figure 7. This figure also indicates that even though the cable TV medium bears the full cost of reverse amplifiers and filters, it will be a relatively low cost system in the near future. Figure 7 also indicates that the multiport bridge system modified to allow the connection of 10 subscriber lines to one subscriber model within a local neighborhood or apartment complex will be a relatively low-cost alternative. The use of this nodule concept as well as dc loops, automatic dialers, and CATV reverse amplification are expected to provide the lowest-cost methods of communication over the near term. As shown in Figure 8, the availability of CATV systems with reverse amplification capabilities in place and multiport bridge-nodule systems are expected to provide the lowest cost methods of alarm transmission over the next 10 to 15 years.

*In constant 1975 dollars.

Radio systems are currently comparatively very expensive because of high initial equipment costs (necessitating a correspondingly large return on investment to the alarm industry) and because of FCC requirements for additional maintenance and annual transmitter calibration. If large-scale-integration components are developed specifically for alarm signal transmission, they could reduce the cost of RF transmission and modem equipment, improve radio system reliability, and reduce radio system costs of operation. Initial equipment costs (transmission and modem units) could potentially be reduced by 50 percent over the next 10 to 15 years.

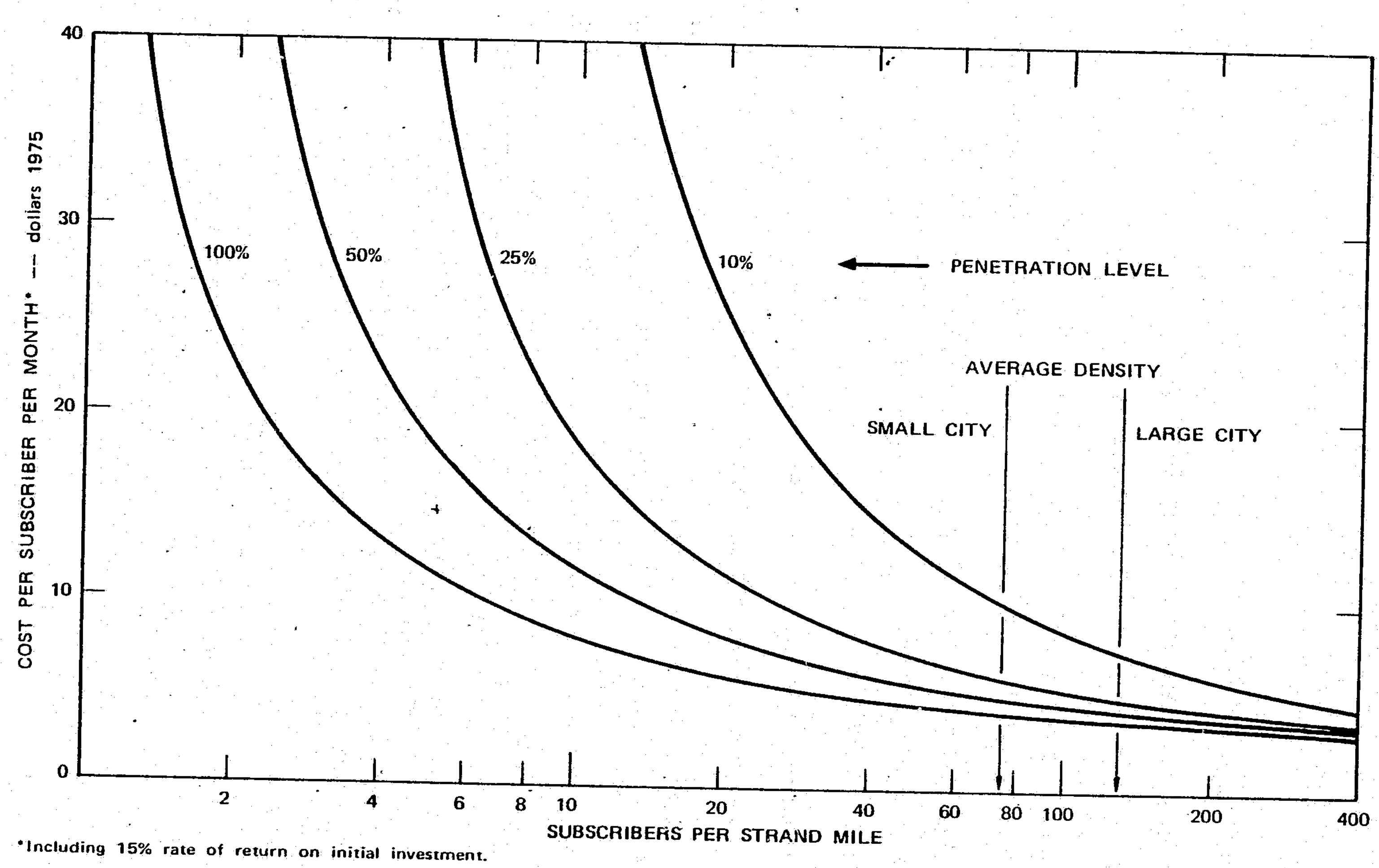
(b) <u>Sensitivity of costs to population density and penetration level</u>. Only two of the transmission media studied, radio and CATV, are highly sensitive to population densities and the range of variations in communication distances found between metropolitan and rural areas. Figures 9 and 10 show the effects of variations in population densities and penetration level on CATV and radio system costs. The CATV and radio costs assume near-term operations within the next 5 years and the TV costs include the expenses incurred in installing reverse amplifiers and filters at the time of cable installation for conventional TV transmission. As shown, the cost of alarm transmission over TV cable can be reduced significantly by increases in the "penetration level," which is defined as the percentage of potential households served. As indicated in Figure 10, monthly costs per household can be reduced more than 50 percent by increasing penetration levels from 10 to 50 percent.

(c) <u>Present value</u>. Another standard method of comparing system costs is to calculate the present value of expenditures using an assumed minimum acceptable rate of return. This method gives full weight to the time value of money and equates varying expenditures over the service life of the system. The present-value method was also used in the analysis,



*Including 15% rate of return on initial investment.

FIGURE 9 RADIO ALARM TRANSMISSION SYSTEM COSTS PER MONTH—CURRENT



*Including 15% rate of return on initial investment.

FIGURE 10 CATV ALARM TRANSMISSION SYSTEM COSTS PER MONTH—CURRENT and the systems ranking based on the comparative costs agree fully with those based on the equivalent-monthly-cost method presented here. The present-value results can be found in Reference 11.

G. Ranking of Evaluation Parameters

The two most important parameters in evaluating competing candidate transmission media/systems are availability and cost.

Several parameters in Table 4 are directly related to, and may, in fact, determine availability of the medium. These are: status of the media/systems, regulatory and policy constraints (such as two-way CATV capability), and dependence on other services (such as interactive two-way services for CATV).

Parameters that are of secondary importance are reliability, (which, in turn embraces resistance to tampering) and expansion (growth) potential.

Parameters judged to be of minor importance in selecting alarm transmission media include bandwidth (and, consequently, the data rate capacity), and error rate (and, consequently, the medium-generated false alarm rate). The three primary candidate media, telephone, CATV and radio, can easily satisfy the rather modest data rate requirements for alarm signal transmission. Medium-generated false alarms can be easily reduced or even virtually eliminated through minimal applications of error detection/correction techniques.

CHAPTER 4. CONCLUSIONS AND RECOMMENDATIONS

On the basis of the results of this study of four potential alarm transmission media (power lines, radio, CATV, and telephone), the following principal conclusions and recommendations are drawn.

A. Conclusions

1. Media showing no or limited promise (or otherwise constrained)

- Cross-town power lines are not available as a transmission medium. Even if available, their use could involve severe technical problems.
- Currently available or readily achievable radio systems are too costly to compete with telephone or CATV media. This is, due to the high equipment costs, as well as the high maintenance costs resulting, in part, from the FCC requirements for licensed operation (for output power in excess of 3 W). In order for the RF medium to be cost/effective for alarm signal transmission, one would need to develop an implementation scheme that would feature long MTBF, ease of installation, and operation at a RF power level of less than 3 W. A capability for channel supervision is also required. The implementation of the improvements listed above is essential to lowering of the RF system equipment, installation, and maintenance costs to levels where the RF medium costs may begin to be cost competitive with those for the telephone or the CATV medium. This study did not establish whether the RF power levels below 3 W and those permissible for non-licensed operation can be sufficient for reliable transmission of alarm signals. In the absence of breakthroughs in RF system costs and simplification of operation requirements (regarding FCC regulations), radio appears to show little promise as a potentially cost/effective alternative.
- Unconventional media such as lasers, microwave, optic fibers, and water lines appear impractical and/or costly.

2. Media showing good promise. The study focused on the best transmission system alternatives for two categories of burglar alarm service: Conventional, commercial, high-reliability alarm service, and low-cost, residential/small-business alarm service, suitable for low-income subscribers.

(a) Conventional, commercial alarm service. The systems that appear promising through the 1980s are:

- Telephone--multiport bridge systems (particularly the AT&T "closed window" bridge under development).
- CATV--in those areas where widespread CATV coverage exists, particularly if and when two-way capability is implemented for other (non-alarm) applications. The degree of utilization of this medium depends on realization of its growth forecasts. (Best available forecasts are: 75 percent of households in the United States will be fronted by CATV in the mid-1980s.) The actual growth of this medium and widespread implementation of two-way capability will depend on economic viability, and only in lesser degree on FCC regulations. The technology of interactive services, including that of CATV transmission, is well developed.

(b) Low-cost burglar alarm service. The promising systems include:

- Telephone--auto-dialer systems. These represent a universally available, low-cost solution, although some problems may still exist, including low reliability and the fact that some municipalities have outlawed this form of alarm service to summon the police.* Although practically all desirable features may already have been incorporated into some existing auto-dialers, the "optimum" dialer for this service has not been specified; some improvements in reliability may be necessary. Costs of the non-telco dialers could be reduced further if the requirement for a telephone-company-supplied interface device (not required with telco dialers) could be eliminated.
- CATV--This system may ultimately represent the lowest cost, long-term solution, provided that this medium achieves the predicted extensive coverage and two-way transmission capability for other (non-alarm) interactive services and its costs are sunk.

*The reasons for this include potential saturation of police communications through false alarms, particularly in the event of electrical storms, earthquakes, or other phenomena that might trigger automatic alarms; also unwillingness to accept recorded messages. See Reference 20.

B. Recommendations

In evaluating candidate transmission media/systems for alarm signaling applications to determine the most promising, SRI did not uncover any major gaps in technology or in other areas where intensive follow-on studies or further technical development under LEAA/Aerospace sponsorship would be expected to yield large payoffs. This is primarily because many of the media operators and media equipment developers have already undertaken and/or completed such needed development, e.g., the CATV equipment manufacturers, and the "closed-window" multiport bridge undergoing development by AT&T through their Bell Telephone Laboratories subsidiary. Also, the use of some candidate media is economically constrained and additional technological developments cannot be expected to expedite the future availability of the medium; this is clearly the case with CATV. Nevertheless, this study uncovered some secondary problem areas and technological gaps that warrant further exploration, the resolution of which can be expected to decrease the alarm system costs and/or improve their reliability. Accordingly, the following recommendations are made:

1. Power lines. Cross-town power lines do not represent a viable option for alarm transmission; thus, further analysis of this medium should be discontinued. If widespread RF carrier communications systems via power

lines were to be implemented by the electric utilities for their own applications, a second look at the potential availability and utility of this medium for alarm signaling applications may be warranted.

2. Telephone

(a) Development efforts by the telephone companies and manufacturers of systems that are to replace previous alarm signaling methods via the telephone medium are well under way (e.g., the AT&T "closed window" bridge). No need for additional funding by LEAA exists in this area.

(b) A study should be undertaken to develop a set of requirements for auto-dialers for low-cost alarm signaling transmission.

(c) The current requirements for telephone-company supplied couplers between non-company auto-dialers and the telephone plant should be reexamined. The results should be communicated to state public utilities commissions, particularly in those states where this requirement is being disputed or is under litigation, in order to help resolve this issue.

3. Radio. The feasibility should be established of reliable RF alarm signal transmission systems with power levels below those requiring annual inspection and calibration under FCC rules, and with levels low enough to permit operation under the non-licensed category of the FCC operation. If reliable operation is infeasible, then further evaluation of this medium should be discontinued. If feasible, then further study aimed at improving equipment reliability and reducing its costs should be undertaken. If non-licensed alarm operation is infeasible, then the FCC should be petitioned to establish a new service category for radio alarm service.

4. CATV. Since the growth of two-way CATV systems depends largely on the economic viability of services requiring two-way capability rather

than on technology development or FCC regulations, no specific recommendations regarding this medium are made. The FCC should be informed that if widespread implementation of low-cost burglar alarm systems should take place, the two-way CATV medium will be a strong contender for this service.

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