SYSTEMS ENGINEERING APPLIED TO THE DEVELOPMENT OF A COMMUNITY TELEVISION RECEIVING SYSTEM

by

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(ABSTRACT)

This report examines a variety of alternative television systems to meet the needs of a sample community for the upgrade of television reception for news, education and entertainment. These alternatives include cable, local broadcasts and satellite systems. An estimated life cycle cost analysis is performed for the systems considered. A detailed design and suggested system configuration is developed for the most cost effective alternative.

The system proposed for the community was a combination of local and satellite television which would be received at a common area within the community and then distributed to each home. The type of system developed is referred to in this report as Shared Antenna Community Television (SACT).

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

1.0 INTRODUCTION

Television has become an important commodity in current society, relied on by many for the purpose of delivering news, entertainment and educational services. The ability to receive television within a given area varies throughout the United States. Many communities and individuals only have access to a limited amount of what is readily available in television broadcasting and could easily identify deficiencies in their available reception capabilities.

This report analyzes a scenario in which a small community expresses dissatisfaction with what is available to them in terms of news and entertainment. A survey of the community has shown that improving the selection of available television programming would be a major step in alleviating the deficiency. In response to the survey, the community homeowners association has committed to a study of various means of upgrading television service to the community.

The report examines a number of feasible alternatives for upgrading the community television reception capabilities, including cable, satellite and terrestrial television. One of the alternatives is selected as the best system for the sample community by stepping through the systems engineering process as illustrated in Fig. 1. The systems engineering process begins by defining a need for the system. Following a definition of the need, operational and maintenance requirements are defined. Then a preliminary design is performed which includes a functional analysis, preliminary analysis and requirements allocation. The preliminary design process selects the best alternative based on system tradeoffs and life cycle costs. The system engineering process concludes with a detailed design of the selected alternative with continued consideration of the system over its life cycle.

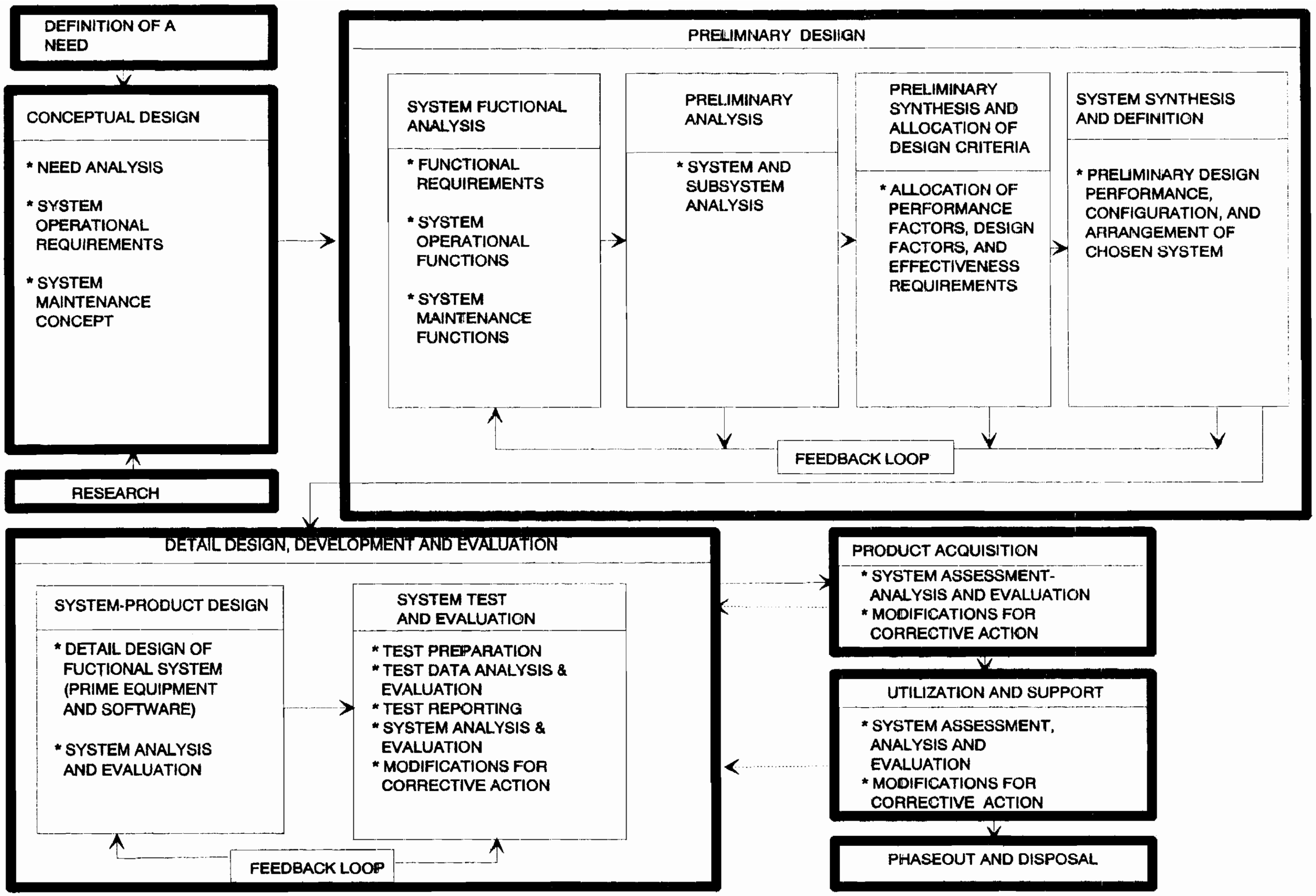

Figure 1. Applied version of The Systems Engineering Process (Blanchard, 1990)

In this scenario, the actual details on the community are factitious, however, all details concerning the upgrade to the television capability are true to the south-central Virginia area. The analysis is also applicable to many similar type communities throughout the United States.

1.1 DEFINITION OF THE NEED

The sample community, Twin Meadows housing development, located in Downscreek, Virginia, is a somewhat remote community of 20 homes on wooded 1/2 acre lots. An illustration of the Twin Meadows housing development is given in Fig. 2. The residents of the community include all ages and backgrounds with the medium income level at approximately $40,000. Due to the remote location of the community, it can only receive limited television service. The community is approximately 120 km from local transmitters in Roanoke, VA, and 70 km from transmitters in Bedford, VA. These distances from the transmitters place the community, on the fringe of service for local channels (ABC, CBS, NBC, FOX) which is defined as "Grade B" service by the Federal Communication Commission (FCC). Furthermore, the community is not serviced by a cable company and none of the residents are allowed by covenant to have their own antenna or receiving systems to get better local or any other type of broadcasts.

A survey of the community shows that this limited capability is no longer acceptable to the residents. Television is considered by the residents as a tool for delivering news and entertainment. For television to be useful in this purpose, the residents require better picture quality (equivalent "Grade A" service), better signal availability (99.9%) and a larger selection of programming such as CNN, C-SPAN, ESPN, VH1, CMT, TMC, AMC, DISNEY, HBO, CINEMAX.

As their two main options, the residents in the community may choose to

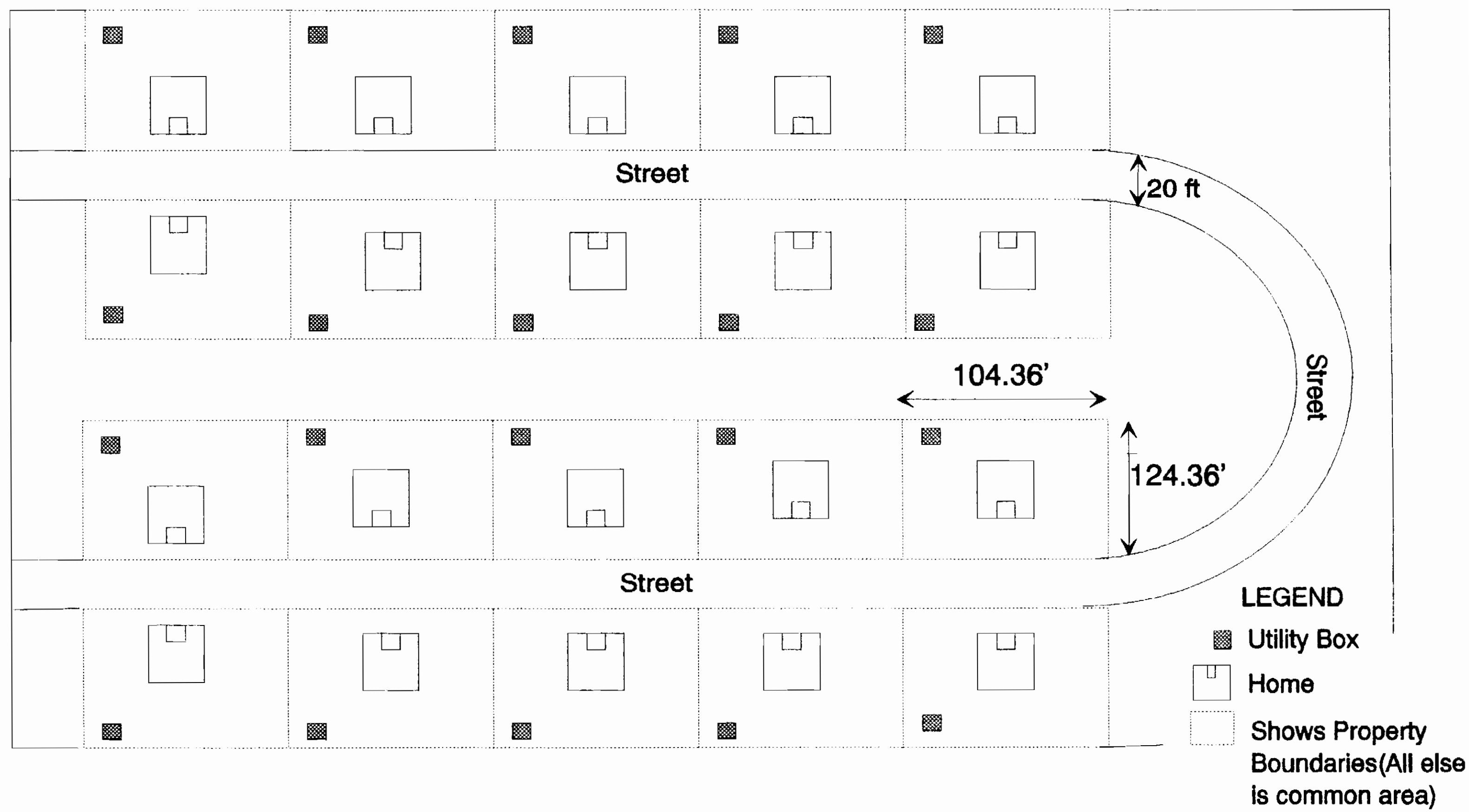

Figure 2. Layout and property boundaries of the Twin Meadows housing development. All properties are on half-acre lots

improve the situation on their own or they may act as a community to solve the common deficiency. The decision of the residents, also indicated by the survey, was that they are willing to work as a community to study the situation and determine the most cost effective solution. Towards this end, the community established a baseline for their system with standards for the programming, performance, size and cost.

1. Programming selection shall include 30 channels (minimum):
   - Local television stations ABC, NBC, CBS, FOX
   - Selection of other stations including channels in the areas of news, sports, music and movies such as CNN, C-SPAN, Headline News, ESPN, ESPN2, MTV, VH1, CMT, TMC, AMC, DISNEY, Weather Channel, Sci-Fi Channel, The Family Channel. A&E, Nickelodeon, USA Network, The Learning Channel
   - Pay channels such as HBO, Cinemax, Showtime and pay-per view channels

2. Performance:
   - Equivalent Grade A service as defined by the FCC(Federal Communications Commission)
   - System operational availability 99.9%

3. Size (If the system includes terrestrial or satellite antennas):
   - Individual Homeowner Antenna System < 8 ft
   - Group Antenna < 18 ft

4. Cost:
   - An initial survey of what types of services are available shows that an initial cost of approximately $300 to $2000 dollars is

reasonable for an individual system which may include television from local sources and satellites. As a result, the recommended system shall also cost between from $300 to $2000 per homeowner.

Furthermore, an agreement was made that the community will support the cost of a study to determine the best alternative for the community and support the financial costs of the recommended system given a positive vote from all homeowners. It is expected that any initial and continuing maintenance costs for a community system will be split among the 20 homes.

1.2 FEASIBLE ALTERNATIVES

Three alternative systems shall be considered for providing television service to the community. These alternatives are as follows:

1) Extend cable service from the nearest cable company to the Twin Meadows housing development. The cost for extended cable service will be equally distributed to each homeowner.

2) Allow individuals to own and operate their own television receiving systems with limits on the antenna or dish size. This option changes a policy instituted by the homeowners association which had opposed satellite dishes or large terrestrial antennas due to aesthetic reasons.

3) Design a single television receiving system at the site of the housing development which can distribute television throughout the community. The cost of the initial system construction and further maintenance will be distributed to each homeowner through the homeowners association.

The need described in this introduction is addressed in the remaining chapters of this report. The initial conceptual design of alternative systems is developed in terms of the operational and maintenance needs of the systems. Preliminary system designs and cost analyses are then considered to the level necessary to make a system recommendation. Finally, a detailed system design is presented for the recommended Shared Antenna Community Television (SACT) system, followed by a summary of the report, conclusions and recommendations.

2.0 CONCEPTUAL DESIGN

The conceptual design of this Chapter follows the definition of the need of Chapter 1 in the systems engineering process. In the conceptual design phase, major operational requirements and maintenance concepts are established for the system. The operational requirements and maintenance concepts establish boundaries for the system which apply regardless of system or hardware configurations.

2.1 OPERATIONAL REQUIREMENTS

The purpose of the operational requirements is to define the major operating conditions for the system. Operating conditions include: how the system is to be used, how it is to perform, how it is to be deployed and a definition of the environmental conditions the system will be required to operate under.

2.1.1 System Profile

The system is to provide a "Grade A" television signal to the input of each individual entertainment system, which could include multiple televisions or VCRs. The system will accomplish this by having the capability to receive and distribute a minimum number of available television stations.

A community survey showed that the households consisted of a varied group of people whose interests in television covers a spectrum of news, entertainment and educational television. A list containing an exact group of acceptable television stations is difficult. The system, therefore, should be flexible so as to accommodate most everyone. The goal of the system is to offer the maximum flexibility in channel selection with the recognition that there may be compromises on some specialty or pay per-view channels.

The community survey also indicated the time extent and periods of the community television viewing. The community survey indicated that the average home viewing included from 4 to 5 hours of television a day. The time of day the community was watching television varies. Fig. 3 shows, on average, when each

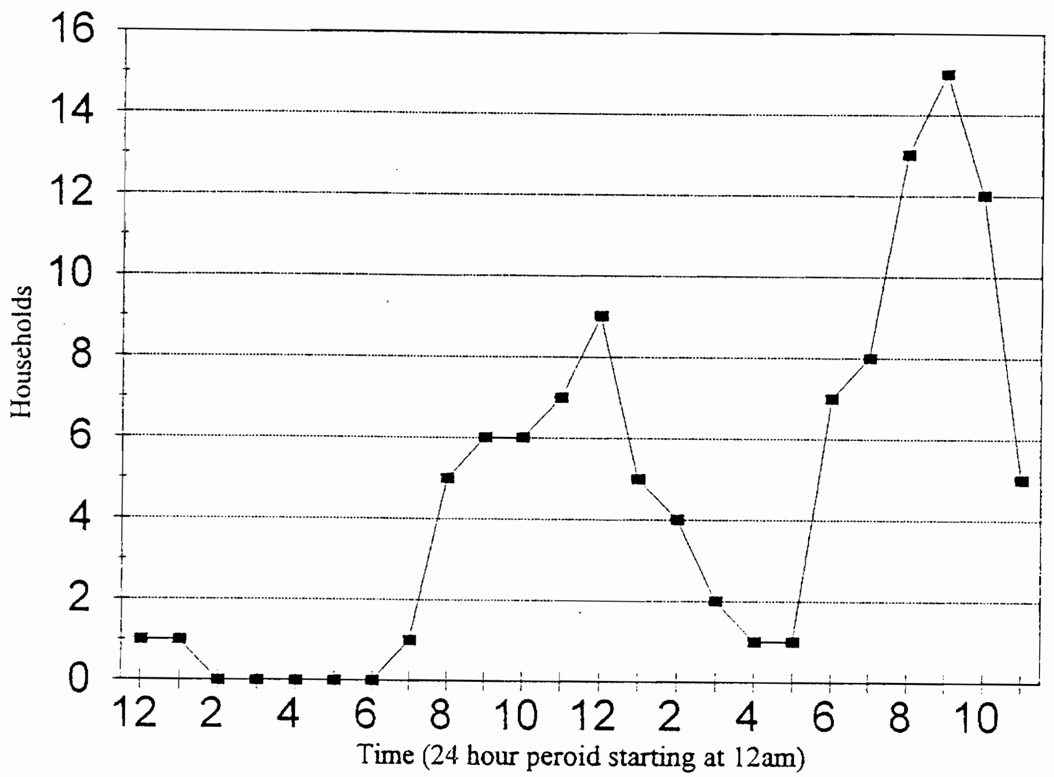

Figure 3. System profile of the usage requirement for the television receiving system. The figure shows on average when each household watches television.

household is viewing television. The times shown are an average of the occupants living in the household. The peak times range from 10 am to 1 pm in the afternoon and from 7 pm to 11 pm in the evening. The community survey also indicated an expected lifetime for the system of at least 10 years for an expected amount of anticipated investment.

2.1.2 Performance Factors

The standards for television transmission have been established in the United States by NTSC(National Television Standards Committee). Each terrestrial transmitted television station is allocated a bandwidth of 6 MHz in the frequency spectrum as shown in Fig. 4. The picture is transmitted via an amplitude-modulated carrier with a portion of the lower sideband removed by filtering to conserve bandwidth (referred to as vestigial sideband or VSB). The sound is transmitted via a frequency-modulated carrier located 4.5 MHz above the picture carrier (Krauss, Bostian & Raab, 1980).

The requirement for the signal power level shall include a minimum signal level, maximum signal level and minimum signal to noise ratio at the input to the individual entertainment system. In the case of local television stations or terrestrial television, the minimum signal level shall adhere to the standards defined by the FCC. The desired requirement for the community is the system shall deliver a signal at the input to the individual home entertainment system at a signal level which is equivalent to "Grade A" service. "Grade A" service is defined by the FCC to be a minimum field strength which would extend an estimated radius around the source of the broadcast (Telecommunications, 1994). Table 1 specifies the standards set by the FCC for all terrestrial broadcast channels 7 through 69. Table 2 translates the field strength values shown in Table 1 to a power level measured at the input to a television set. The calculations in Table 2 take into account the transmit frequency of the terrestrial television station and assume 0 dB gain for the receiving system.

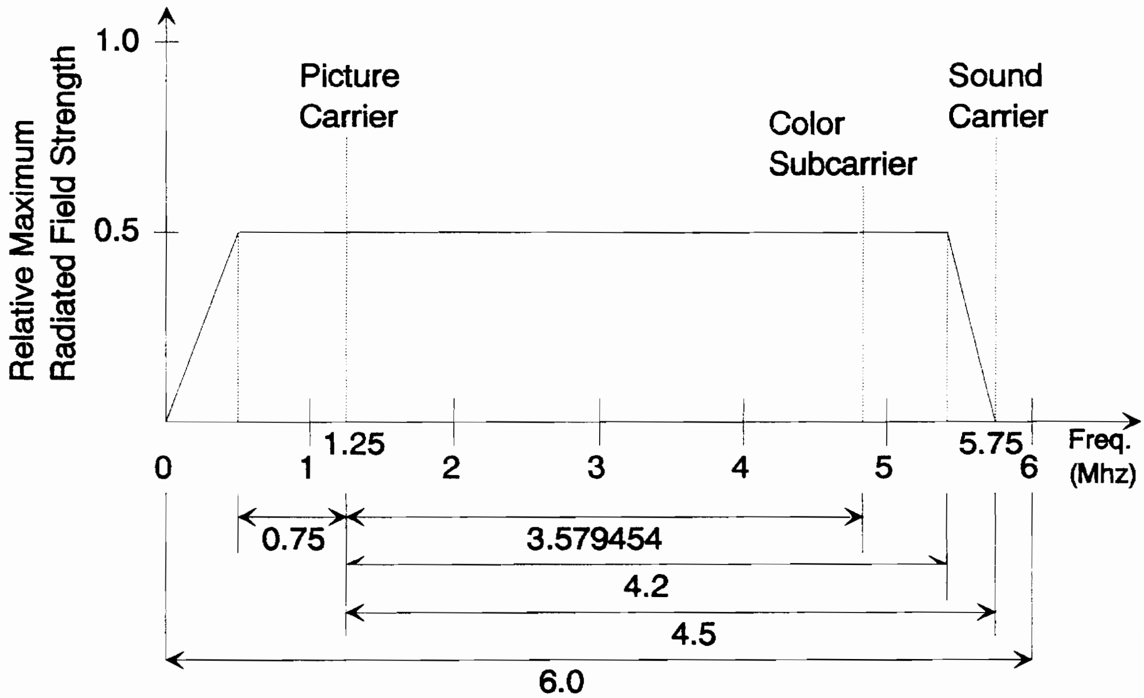

Figure 4. "RF amplitude characteristic of a television picture transmission" *(Krauss, et al. 1980, p.333)*

Table 1. FCC minimum field strength values for Grade A service (Telecommunications, 1994)

Channel	"Grade A"Field Strength (dbm/m^2)
7 - 13	-44.75
14 - 69	-41.76

Table 2. Expected input power levels at the input to an individual television to qualify for Grade A service according to FCC standards. This assumes a receiving system with an area of $\lambda^2/4\pi$.

Channel	Frequency (Mhz)	Field Strength (dBm/m^2)	Affective Area(Ae) (dbm^2)	Received Power(Pr) (dbm)
7	180	-44.75	-6.55	-51.30
10	198	-44.75	-7.38	-52.13
13	216	-44.75	-8.14	-52.89
21	518	-41.76	-15.73	-57.49

The maximum signal level for the terrestrial signal at the input to the entertainment system shall be - 5 dbm and the minimum signal-to-noise ratio shall be 20 dB. The -5 dBm maximum signal level is characteristic of what is expected of cable television systems to avoid distortion while the signal-to-noise ratio requirement limits signal to an acceptable level of background snow or noise (Homer, 1995).

If the system includes a satellite receiving system, the required signal level shall be dependent on the satellite receiver. Table 3 shows minimum and maximum signal levels which are typical for a satellite receiver (Broad Band Communications Products, 1994). Furthermore, the signal shall have a minimum signal-to-noise ratio of 11 dB (Pratt & Bostian, 1986). It is assumed in this report that if the specifications for the satellite receiver are met, the specifications for the system will be satisfied.

Table 3. Minimum and Maximum Signal Level Requirements for a Satellite Receiver

Channel	Minimum Input power to a Satellite Receiver (dbm)	Maximum Input power to a Satellite Receiver (dbm)
7 - 69	-65	-25

2.1.3 Operational Deployment

The television receiving system will be deployed at the Twin Meadows housing development. The system must be able to provide service to the 20 homes in the housing development.

2.1.4 System Effectiveness Factors

The operational availability(A_o) of the system shall be 99.9 % over a 1 year period. This translates to a down time for the system of a maximum of 8.76 hours per year. A reasonable maximum value for the Mean Down Time(MDT) for the system was selected at 8 hours. A shorter two hour MDT may be obtained with a coordinated effort established within the maintenance concept to quickly identify problems at an organizational level so that corrective or scheduled maintenance actions are handled efficiently.

The Mean Time Between Maintenance(MTBM) is related to the operational availability and MDT in Eq. 1. It is assumed that the MTBM of the system is a reasonable approximation of the Mean Time Between Failures(MTBF). Given this assumption, the system required MTBF is calculated to be 7992 hours or 11.1 months.

$$Ao = \frac{MTBM}{MTBM + MDT} \qquad (1)$$

2.1.5 System Environment

The development is located in South-Central Virginia. The extreme temperatures in this region range on average from -11 to 105 degrees Fahrenheit (Blair, 1994). In all the feasible alternatives, a portion of the system will be located in an outdoor uncontrolled environment and a portion will be located in an indoor controlled environment. Portions of the system which are located in an outdoor uncontrolled environment must operate within the extreme temperature range of:

Uncontrolled Environment: -11 to 120 degrees Fahrenheit

Furthermore, outdoor system components must maintain performance specifications in all weather conditions with the exception of extreme weather conditions such as a hurricane or tornado. Portions of the system which are located in an indoor controlled environment must operate in the following temperature range:

Controlled Environment: 40 to 90 degrees Fahrenheit

2.2 MAINTENANCE CONCEPT

The purpose of the maintenance concept is to establish the boundaries and capabilities of the homeowners association as well as the system component suppliers to service and maintain a system. The homeowners association has developed a maintenance concept which defines three levels of maintenance: organizational, intermediate and depot. The organizations or individuals which fall under each level of maintenance along with their responsibilities are given in the following sections.

2.2.1 Organizational Level Maintenance

Organizational level maintenance includes all maintenance functions carried out by the individual homeowners or employees of the homeowners association. Employees of the homeowners association will be responsible for monitoring any equipment located in the common areas of the community.

In the case of extending cable to the housing development or allowing for individual receiving systems, the individual homeowners will be responsible for the cleaning, general upkeep and visual inspection of the cable or equipment. Required maintenance will be referred to individuals at the intermediate maintenance level.

In the case where the community decides on a group receiving system, the community will require one individual with basic skill levels to maintain the receiving and auxiliary equipment located throughout the common areas of the housing development. The individual would not require special skills, allowing the assignment of the same individual to maintaining other common areas of the community. The responsibilities of this individual employed by the homeowners association will include:

1) Maintain cleanliness and general upkeep of common area equipment
2) Complete periodic visual inspections of the equipment for noticeable equipment problems. Report problems to intermediate

maintenance level for repair.

3) Report and coordinate maintenance actions with the intermediate maintenance organization to ensure a MDT of 8 hours.

2.2.2 Intermediate Level Maintenance

This would include scheduled and unscheduled maintenance to be performed on all equipment on-site. In all cases it is expected that a servicing agreement would be reached with the supplier of the cable or receiving system such that they are responsible for scheduled and unscheduled maintenance on-site. The responsibilities of intermediate maintenance personnel would include:

1) Respond on-site to the housing development with the capability to diagnose and replace defective components with a Mean Down Time(MDT) of 8 hours.
2) Stock and supply replacement components
3) Perform any required scheduled maintenance for the system.

2.2.3 Depot Level Maintenance

Depot level maintenance includes the maintenance functions carried out by the equipment manufacturers, including a variety of cable, receiving/distribution equipment suppliers. The responsibilities of depot level maintenance personnel include:

1) Provide replacement parts and components to the intermediate maintenance level.
2) Repair or replace cable or receiving/distribution equipment.

3.0 PRELIMINARY SYSTEM DESIGN

The preliminary design phase is the prerequisite to the detailed design process. The preliminary design includes a functional analysis, preliminary system analysis, the requirements allocation process and a summary of the feasible alternatives. The functional analysis illustrates what the system must do regardless of system configuration or hardware components. Following the functional analysis, the preliminary system analysis which serves to establish a baseline or basic system configuration. A preliminary system analysis leads to the requirements allocation process which begins the process for the selection of hardware components for the system as well as establishing system boundaries based on the specifications identified in the operational requirements, Section 2.1.

3.1 FUNCTIONAL ANALYSIS

The purpose of the functional analysis is to identify *what* functions the system must perform throughout its life cycle. The functions identified are used for selecting system configurations and specific hardware components which show *how* the system will perform. Fig. 5 illustrates the major top level functions necessary in the system's development throughout its life cycle. Each block in Fig. 5 may be expanded to identify subfunctions in each category. In the example given in Fig. 5, the block titled "Operate Television Communications System" is expanded in Fig. 6.

Fig. 6 illustrates both the first and second level diagrams for the block referenced in Fig. 5. The first level diagram lists the major system functions including receiving a signal, distributing a signal and so forth. The second level diagram expands each higher level function given in the first level.

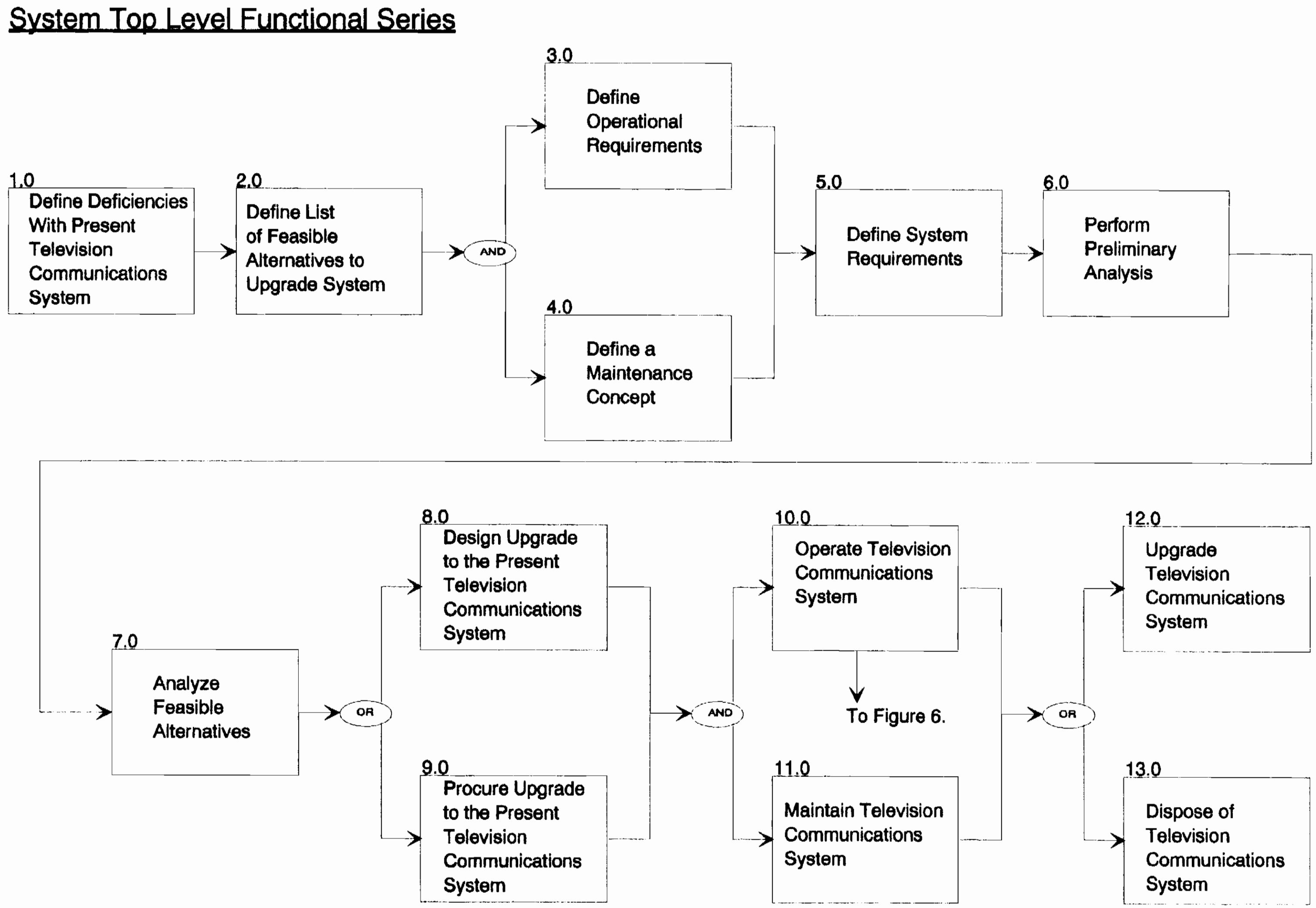

Figure 5. Top level functional diagram of the Systems Engineering process to develop a television receiving system.

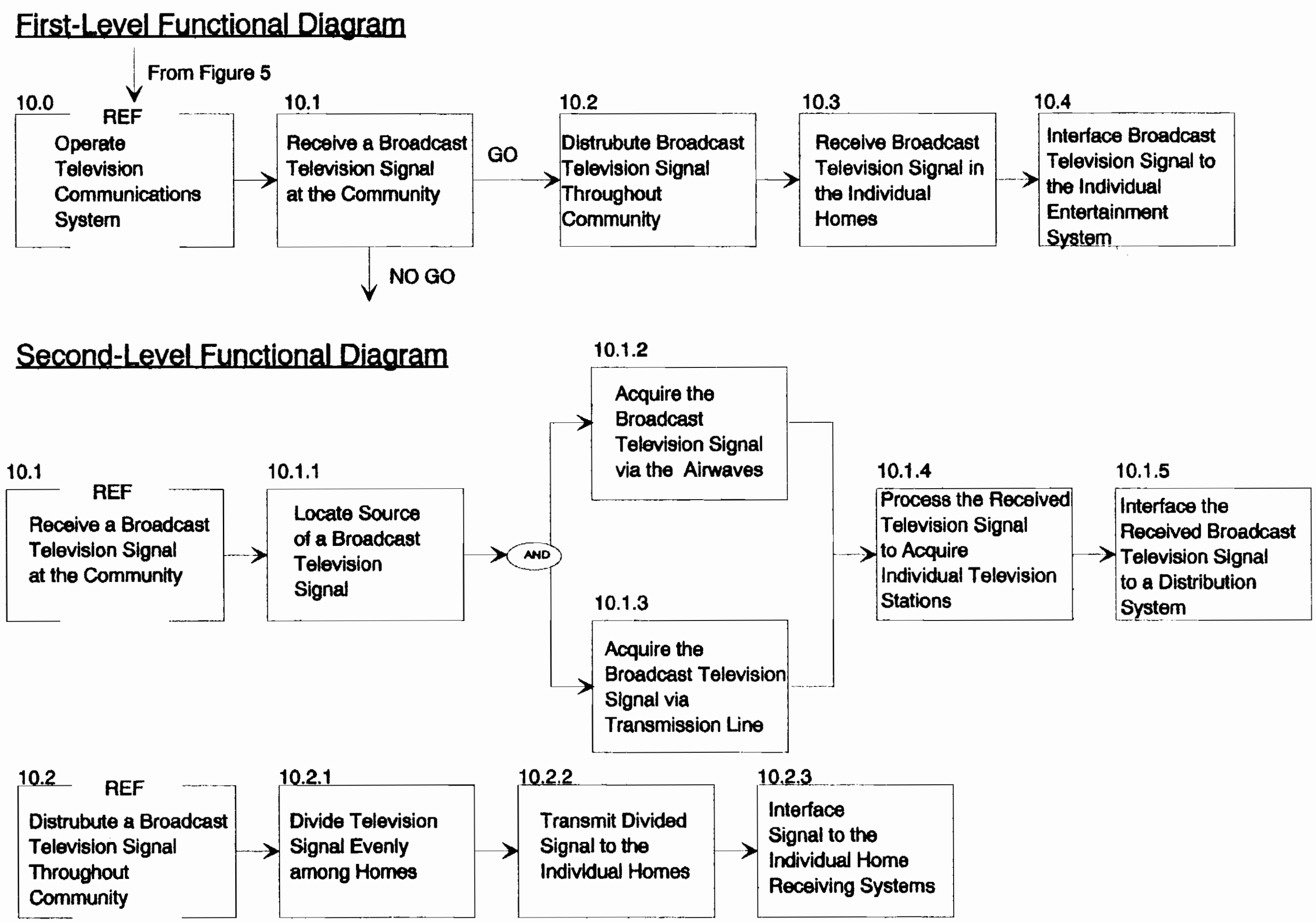

Figure 6. First level functional diagram and a portion of the second level diagram for the television receiving system.

Second-Level Functional Series

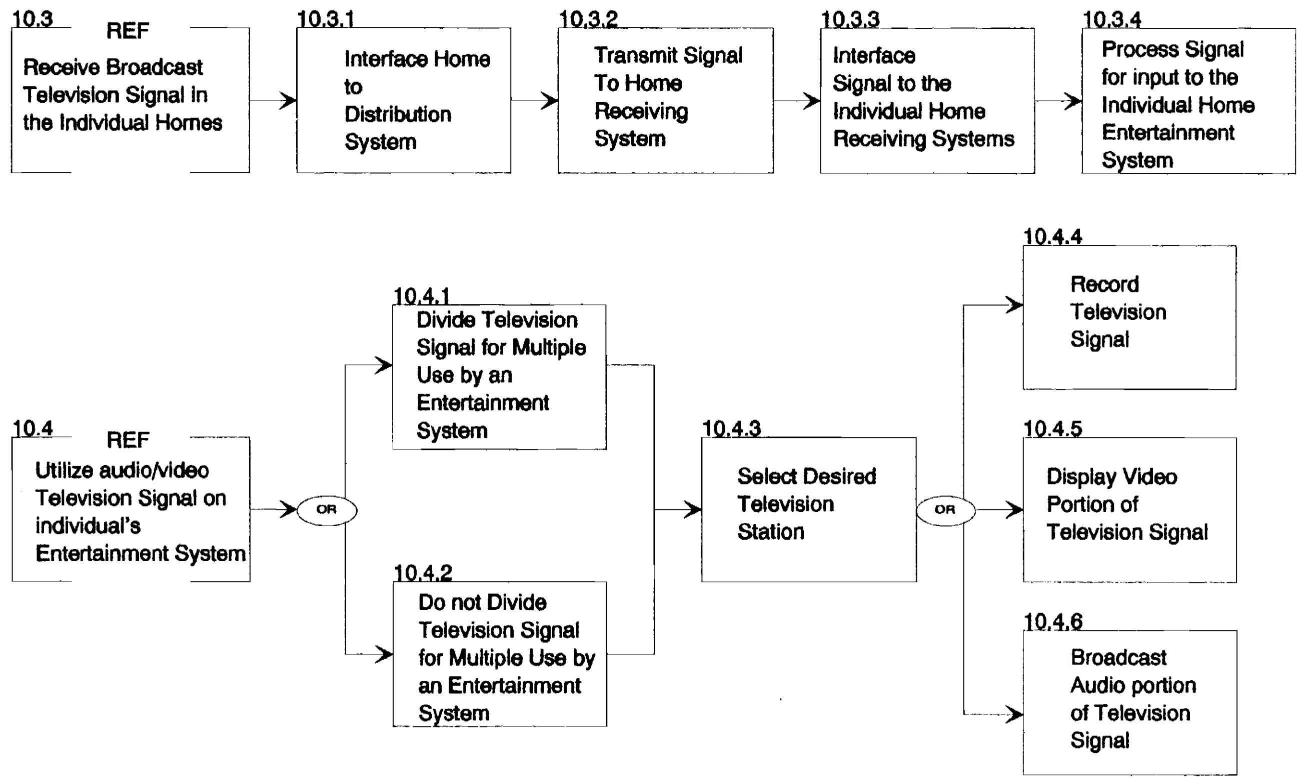

Figure 6 (continued). Second level diagram for the television receiving system.

Fig. 7 illustrates an example of the steps taken during a required maintenance action on the television receiving system. The block used, "Receive a Broadcast Television Signal at the Community", was taken from Fig. 6. The same steps apply to all components of the system and should flow with what has been established earlier in the maintenance concept.

3.2 PRELIMINARY SYSTEM ANALYSIS

The purpose of the preliminary analysis is to expand on the elements that have been identified in the functional analysis and quantify *what* needs to been done with more specific *hows*. In this case, the preliminary analysis examines what broadcast television stations are available to the community and what are the basic system components required to receive them. The analysis of available sources is broken down into two main sources in this report to include local programming or terrestrial television and satellite television.

Local programming in the Twin meadows is available via terrestrial television broadcast towers located in Roanoke and Bedford, Virginia. Local programming stations can range in transmit frequencies from 174 MHz -216 MHz for channels 7-13 and 476 MHz to 620 MHz for channels 15-38 and conforms to the NTSC standards discussed earlier in Chapter 2. Local programming can be received either by an individual entertainment system, cable, or an external antenna system. The community requires cable or some type of external antenna system. Present individual systems do not allow sufficient sensitivity for reception.

Satellite programming would be available to Twin Meadows either through cable or some type of home or community satellite system. Satellite television is transmitted through the use of transponders on a number of orbiting satellite

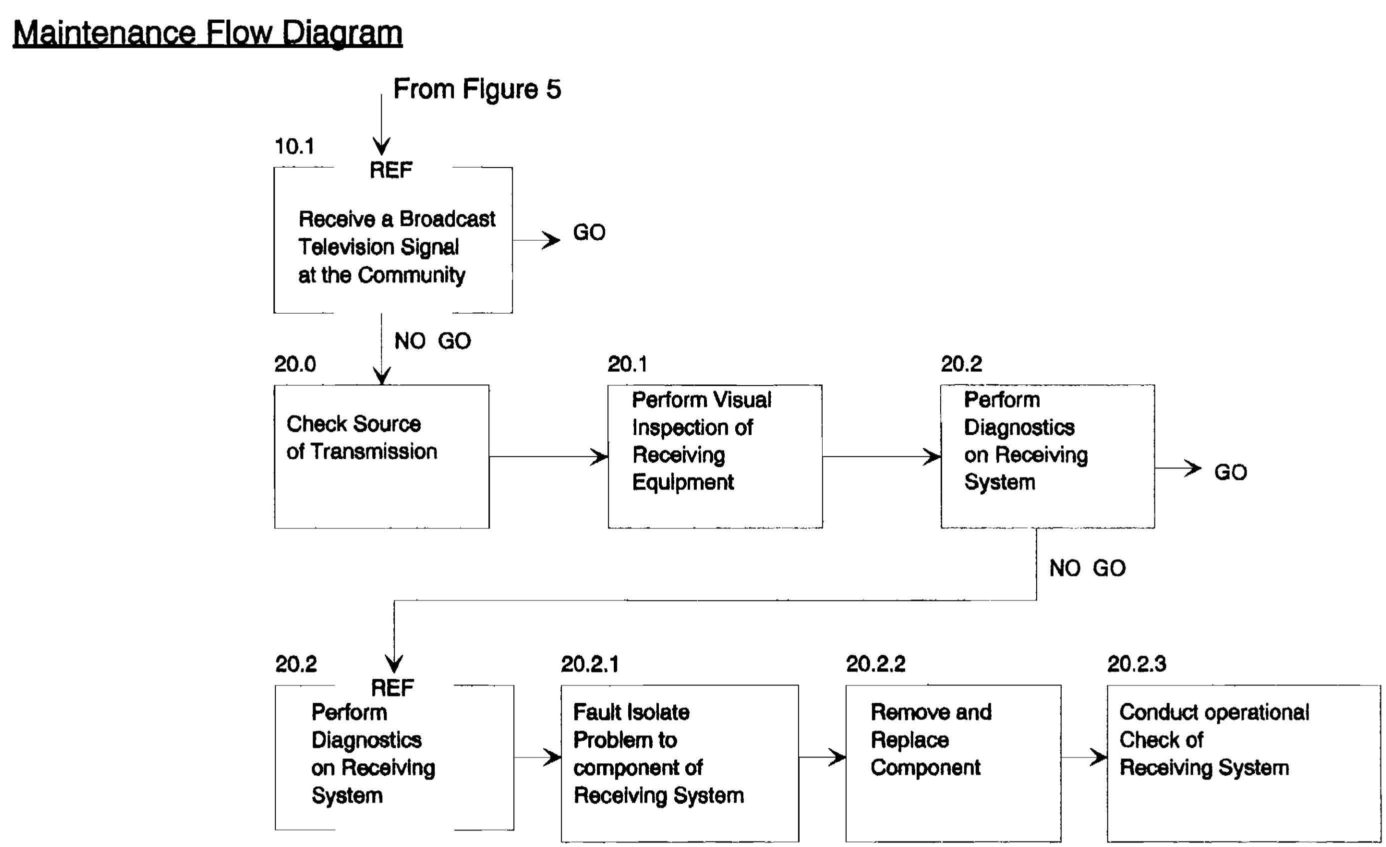

Figure 7. An example of the maintenance flow diagram for the television receiving system

systems. A satellite may have 12, 16 or 24 transponders. Each transponder can transmit either a single television channel or multiple channels depending on the format of the transmitted signal and multiplexing scheme used. A satellite transmission is in a significantly different format than used for terrestrial television. To make the signal compatible to a standard television, the satellite signal is received by an earth station and translated to conform to the NTSC television signal standards (Pratt et al, 1986).

At present, there are three different types of systems offering satellite television programming. The three types of services are denoted in this report as either "analog C-band", "analog Ku-band", or "digital Ku-band". The amount of programming available in the analog Ku-band is limited, thus it is no longer considered as an option. The analog C-band and digital Ku-band systems offer somewhat similar programming packages, but differ in transmit frequency, signal modulation scheme and accessibility (Pratt et al, 1986).

The FCC has allotted a total of 500 MHz to be utilized by satellite systems for commercial broadcast television. The 500 MHz allotment is across a variety of operating frequency ranges. The C-band systems transmit in the frequency range from 3.7 to 4.2 GHz. Ku-band systems transmit in ranges 10.95 to 11.70 GHz, 11.7 to 12.2 GHz and 12.2 to 12.7 GHz. The digital Ku-band system operates in the range from 12.2 to 12.7 GHz (Pratt el al, 1986).

Satellite systems use various forms of frequency modulation(FM) to transmit television. The two main forms of FM include either analog FM or digital FM (Pratt et al, 1986). In analog FM, the transmitted information is frequency modulated around a carrier frequency where the modulation is in direct proportion to the information which is to be conveyed. In digital FM, the information is modulated in discrete phase shifts. The discrete phase shifts represent digital states of the information being sent as a digitized analog level.

The type of modulation scheme is important because it is a major factor in determining the number of television signals which may be transmitted per satellite. The number of channels transmitted per satellite plays a major role in how the satellite may be accessed. Analog FM signals are best suited for frequency division multiplexing or frequency re-use schemes for increasing the number of channels per satellite. The analog C-band systems employ a frequency re-use method of transmitting orthogonally polarized signals. The two most commonly used orthogonally polarizations are horizontal and vertical. A C-band system will typical use 12 transponders for 12 television stations at one polarization and another 12 transponders for 12 more stations at the same frequencies but at different polarizations. Digital FM signals are best suited for time division multiplexing schemes. In a time division multiplexing scheme, transmitted signals are divided in time and transmitted in different time slots. Satellite systems utilizing this scheme can transmit from 3 to 6 television channels per satellite transponder. The big advantage of this type of system is that more channels can be transmitted per satellite. Since only one signal is being transmitted at a time, the signal can make full use of the satellite transponder power (Pratt et al, 1986).

Programming in C-band is offered by 20 satellite systems, each offering a limited amount of programming(Satellite Orbit, 1995). A partial listing of what is available in C-band programming out of the 20 satellite systems is given in Appendix A. An analysis of the programming shows that the community would be required to receive four of the available satellites including the Galaxy 5, Satcom C3, Galaxy 1R and Satcom C1 meet the operational requirements. The remaining satellites are unnecessary since the programming is either repetitive, foreign or very specialized. For instance programming from the Anik E2 and E1 are Canadian television and Solid.1, Solid.2 and Morerlos.2 are Mexican television.

Programming by digital Ku-band systems is offered by a few satellites, each offering large amounts of programming. There are presently three main services including DirecTV, USSB (United States Satellite Broadcasting) and PRIMESTAR. Each service offers programming being transmitted by one or two satellites. PRIMESTAR was the first to offer service. PRIMESTAR offers approximately 70 channels from one satellite system. USSB offers 30 channels transmitted by 5 transponders from the DBS-1 satellite system. DirecTV offers 150 channels from two satellites including DBS-1 (11 transponders) and DBS-2 (16 transponders). The digital systems offer similar programming as was shown for the C-band systems. The digital systems do not offer some of popular stations such as MTV or VH1, but are continuously expanding there available programming.

In all cases, accessing satellite requires a parabolic antenna system which must be directed at the satellite location in space along with a satellite receiver which can process the modulated and possible encrypted signal. The types of antenna systems available for access to C-band satellite programming can simultaneously receive transmissions from a single, dual or a small set of satellites. In the case of the Ku-band systems, it only requires one small antenna system to access all programming from either PRIMESTAR, DirecTV or USSB.

3.3 REQUIREMENTS ALLOCATION

The requirements allocation process is the first step in translating system requirements into specific design criteria. The allocation process is the distribution of top level requirements to lower levels and subdivisions of the system. This purpose of the allocation process is to provide guidelines to the design teams. The allocation process should prevent individual design groups from developing components of the system which would fail overall system requirements (Blanchard, 1990).

The television is divided into two higher levels of hierarchy including the required equipment and personnel. These hierarchical functions are divided into lower level components identified by the functional and preliminary analysis. Fig. 8 suggests a baseline system and illustrates the allocation of the MTBF between major components in the system.

3.4 FEASIBILITY STUDY SUMMARY

Section 3.3 illustrates a baseline system. This sections summarizes the cost and system configuration analysis determined in Chapter 4, as well as, states some major system trade-off for all the alternatives considered. Its purpose is to furnish the bottom line as to which alternative can meet the operational requirements at the least cost. The system meeting the criteria is analyzed further in Chapter 5 and is recommended as the best option. The cost analysis in Chapter 4 estimates some of the major expenses associated with each alternative. The expenses considered include Investments costs (material and assembly) and operating and maintenance costs. These costs are a part of the overall cost breakdown structure which should be considered over the life cycle of a system.

As a means to compare the alternative systems, estimated Investments costs and operational and maintenance costs where combined to determine each system's "present equivalent value". The present equivalent value was estimated in this report using Eq. 2.

$$\text{Present Equivalent Value} = P + A\frac{(1+i)^n - 1}{i * (1+i)^n} \qquad (2)$$

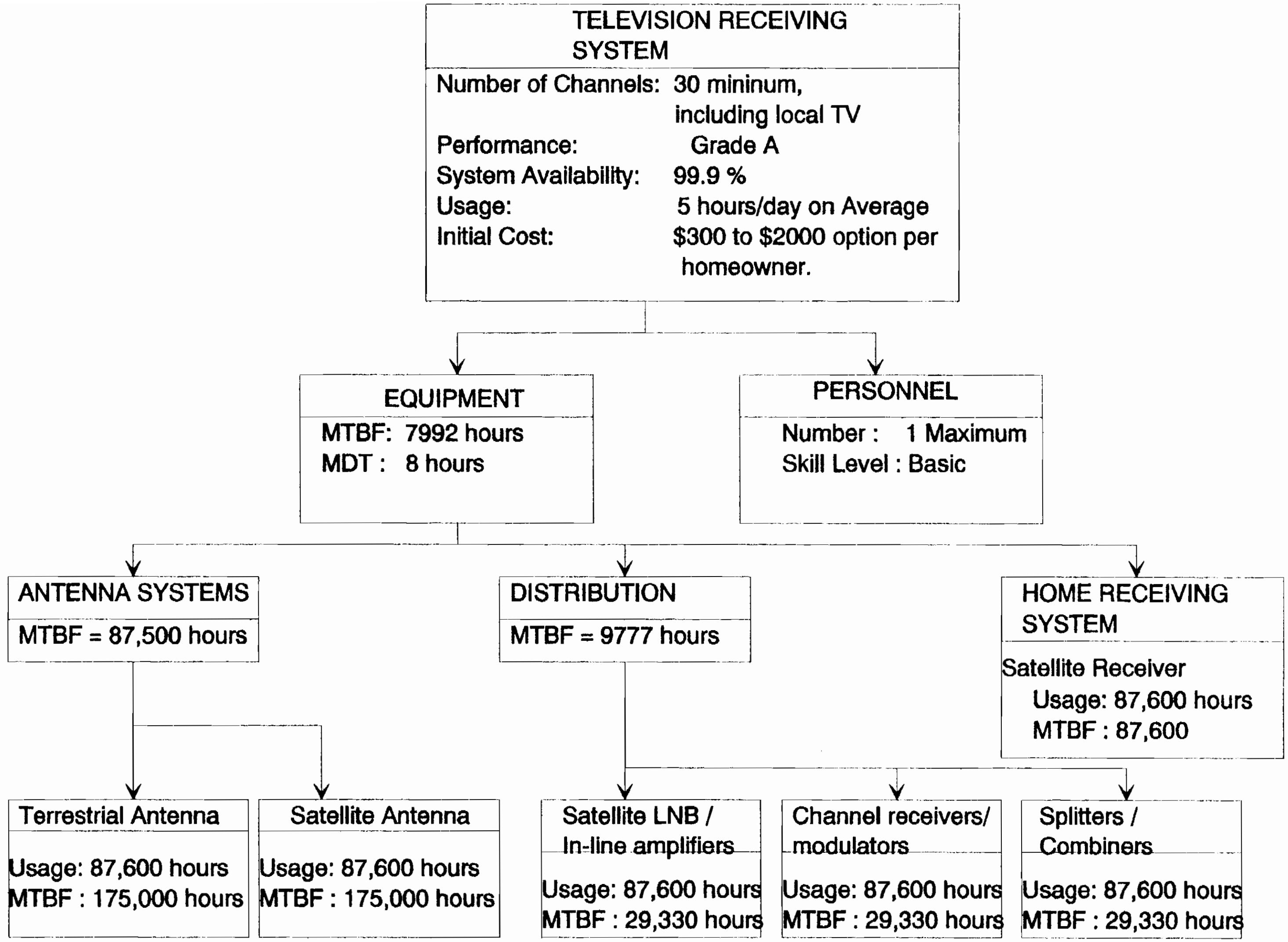

Figure 8. Illustration of the requirements allocation process for the television receiving system

In Eq. 2, P is the system's investment costs, A is the systems annual costs, i is an assumed interest rate which is considered an expense and n is the number or years in the system life cycle. For all alternatives considered the expected life cycle is 10 years and the interest rate is assumed to be 5%. Given these two values the present equivalent for any system is defined by Eq. 3.

$$\text{Present Equivalent Value} = P + A(7.7217) \quad (3)$$

3.4.1 Feasible Alternative #1

The first alternative is to extend cable service from the nearest cable company to the housing development. Cable television is potentially available from TCI[1] cable which is the closest company to the housing development. The main distribution center for TCI cable is located approximately 25 miles from the housing development and the nearest area being serviced by TCI cable is located approximately 15 miles away. It is known at this point that TCI cable has no plans for extending cable service to the housing development area. However, TCI cable can provide service to the community at a cost which has been summarized in Table 4.

The main advantage of cable television is that it can satisfy the operational requirements and the maintenance concept while incurring zero operating and maintenance cost to the community.

[1]TCI is a factitious company, but the estimated installation costs are representative of how a cable company functions.

Table 4. Estimated life cycle costs per individual homeowner for extended cable service to the Twin Meadow housing development

Investment Costs(CI)	
Assembly	$2950.00
Operations and Maintenance Costs (Co)	
Operations(Coo)	
Operational Facilities (Coof)	
Programming	$ 360.00
Present Equivalent Value:	**$5729.81**

3.4.2 Feasible Alternative #2

The second alternative would allow individuals to own and operate their own television receiving systems. This option changes a policy instituted by the homeowners association which had opposed large terrestrial antennas or satellite dishes for aesthetic reasons. At present, there are a number of technologies or systems available which can provide the variety of programming desired and meet the other operational requirements. Available systems include a terrestrial antenna for receiving local broadcasts and a satellite receiving system for receiving all other types of programming. A depiction of a system configuration is given in Fig 9.

The three candidate systems chosen under this alternative included an analog C-band satellite system combined with a terrestrial antenna and two types of digital Ku-band systems combined with a terrestrial antenna. The difference between the Ku-band system is that one is purchased and the other is leased. The first Ku-band type system, termed "Ku-band System #1", is purchased and would provide service from

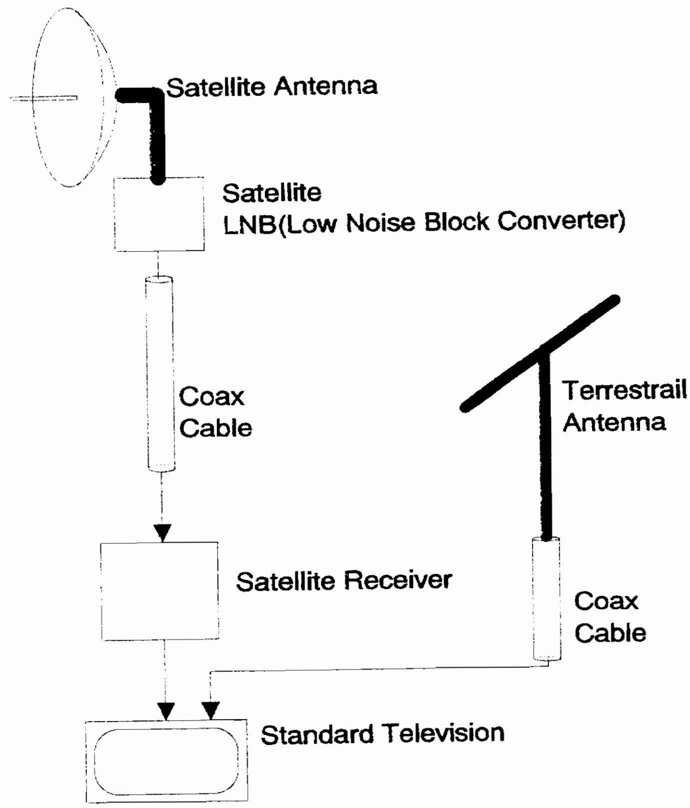

Figure 9. Illustration of a satellite television receiving system(C or Ku-band) and terrestrial antenna. The systems are designed for individual home use.

either DirecTV or USSB. The second Ku-band type system, termed "Ku-band System #2", is leased and would provide service from PRIMESTAR. A summary of the life cycle cost for these three alternatives is given in Table 5.

The main advantage of this alternative is that the individual homeowners can chose a system for themselves, allowing them the most flexibility. Of the three choices within this alternative, the analog C-band satellite system combined with a terrestrial antenna system offers the most programming at a lower or similar cost as

Table 5. Estimated life cycle costs per individual homeowner for three types of personal satellite and terrestrial television systems.

Analog C-band Satellite and Terrestrial Antenna System	
Investment Costs(CI)	
Material	$ 1424.50
Assembly	$ 120.00
Total	$1544.50
Operations and Maintenance Costs (Co)	
Operations(Coo)	
Operational Facilities (Coof)	
Utilities/fees	$ 36.00
Programming	$ 360.00
Maintenance (Com)	
Corrective Maintenance(Com)	$ 110.07
Total	$ 506.07
Present Equivalent Value:	**$5452.22**
Ku-band System #1	
Digital Ku-band Satellite and Terrestrial Antenna System	
Investment Costs(CI)	
Material	$ 904.50
Assembly	$ 80.00
Total	$ 984.50
Operations and Maintenance Costs (Co)	
Operations(Coo)	
Operational Facilities (Coof)	
Utilities/fees	$ 36.00
Programming	$ 360.00
Maintenance (Com)	
Corrective Maintenance(Com)	$ 110.07
Total	$ 506.07
Present Equivalent Value:	**$4892.22**

Table 5(continued). Estimated life cycle costs per individual homeowner for three types of personal satellite and terrestrial television systems. Ku-band System #2

Digital Ku-band Satellite and Terrestrial Antenna System	
Investment Costs(CI)	
Material	$ 404.50
Assembly	$ 80.00
Total	$ 484.50
Operations and Maintenance Costs (Co)	
Operations(Coo)	
Operational Facilities (Coof)	
Utilities/fees	$ 156.00
Programming	$ 360.00
Maintenance (Com)	
Corrective Maintenance(Com)	$ 110.07
Total	$ 626.07
Present Equivalent Value:	**$5318.82**

compared to the digital Ku-band systems. The disadvantage with the C-band system is it has a higher initial cost and requires a large satellite antenna dish (approximately 10 ft in diameter) to receive programming and the community has expressed a definite desire for aesthetic reasons to limit large antenna systems or antenna towers.

The two Ku-band systems, one being purchased and the other leased, offer similar programming. The advantage to leasing equipment is that initial equipment costs are avoided. However, the rented system(PRIMESTAR) has a $10 a month extra equipment rental charge.

3.4.3 Feasible Alternative #3

The third alternative develops a system at the site of the housing development which could distribute television throughout the community. At present, there are a variety of technologies, ranging in complexity, which could be implemented to deliver the required programming and meet the other operational requirements. For this alternative, the community shares parts of a television receiving system which is placed within a common area of the community. Fig. 10 illustrates the concept behind a community system.

There a two major feasible possibilities towards developing a community system. The possibilities include either developing a mini-cable system for the housing development which is the concept behind SMATV(Satellite Master Antenna Television) or a less complex method which would involve simply sharing components of the receiving system such as a terrestrial antenna or satellite dish. The second type of system is referred to in this report as "Shared Antenna Community Television" (SACT). The cost involved for either system will vary with implementation. The analysis in Chapter 4 included a look at three potential systems, two of which are in the SMATV category and one in the SACT category. The cost estimates for these systems are given in Table 6.

A community system has an advantage over individual systems because the homeowners can share cost for required common equipment. As is summarized in Table 6, the SACT system can be provided at a smaller investment and long term cost then any of the other alternatives.

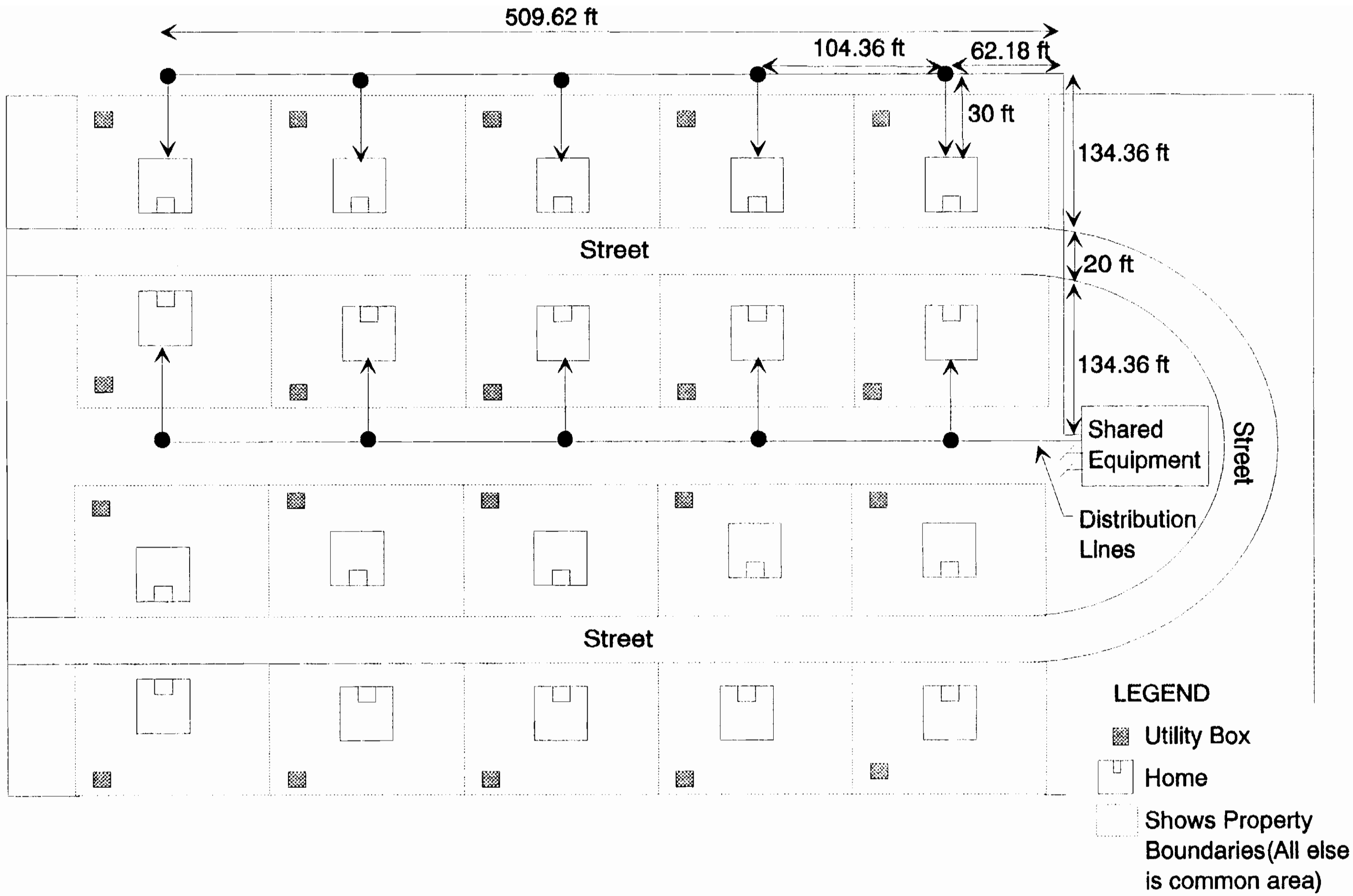

Figure 10. Community television receiving system applied to the Twin Meadows housing development

Table 6. Estimated life cycle costs per individual homeowner for three types of community satellite and terrestrial television systems.

SMATV Analog C-band Satellite and Terrestrial Antenna System	
Investment Costs(CI)	
Material	$3668.00
Assembly	$ 73.40
Total	$3741.40
Operations and Maintenance Costs (Co)	
Operations(Coo)	
Operating Personnel (Coop)	$ 24.00
Operational Facilities (Coof)	
Utilities/fees	$ 37.80
Programming	$ 360.00
Maintenance (Com)	
Corrective Maintenance(Com)	$ 47.54
Total	$ 469.34
Present Equivalent Value:	**$7365.50**
SMATV Digital Ku-band Satellite and Terrestrial Antenna System	
Investment Costs(CI)	
Material	$3598.90
Assembly	$ 73.40
Total	$3672.20
Operations and Maintenance Costs (Co)	
Operations(Coo)	
Operating Personnel (Coop)	$ 24.00
Operational Facilities (Coof)	
Utilities/fees	$ 37.80
Programming	$ 360.00
Maintenance (Com)	
Corrective Maintenance(Com)	$ 47.54
Total	$ 469.34
Present Equivalent Value:	**$7296.30**

Table 6 (contiued). Estimated life cycle costs per individual homeowner for three types of community satellite and terrestrial television systems.

SACT Digital Ku-band Satellite and Terrestrial Antenna System			
SMATV Analog C-band Satellite and Terrestrial Antenna System			
Investment Costs(CI)			
	Material		$ 666.30
	Assembly		$ 71.40
	Total		$ 737.70
Operations and Maintenance Costs (Co)			
	Operations(Coo)		
	Operating Personnel (Coop)		$ 24.00
	Operational Facilities (Coof)		
		Utilities/fees	$ 37.80
		Programming	$ 360.00
	Maintenance (Com)		
	Corrective Maintenance(Com)		$ 39.21
	Total		$ 461.01
Present Equivalent Value:			**$4297.48**

In a comparison of all the varies alternatives, the SACT Ku-band system, has the least investment and long term costs. Furthermore, as will be shown latter in Chapter 5, the SACT Ku-band system can meet the operational requirements listed in Section 1. For these reasons, the SACT Ku-band system is chosen as the best alternative to be developed further in the detailed design process.

4.0 FEASIBLE ALTERNATIVE ANALYSIS ESTIMATING SYSTEM CONFIGURATIONS AND COSTS

This section provides detailed system configurations and life cycle cost estimates for the three feasible alternatives summarized in Chapter 3. A breakdown structure of the costs considered in the analysis is illustrated in Fig. 11. The major categories include investments costs (CI) and operating and maintenance costs (Com).

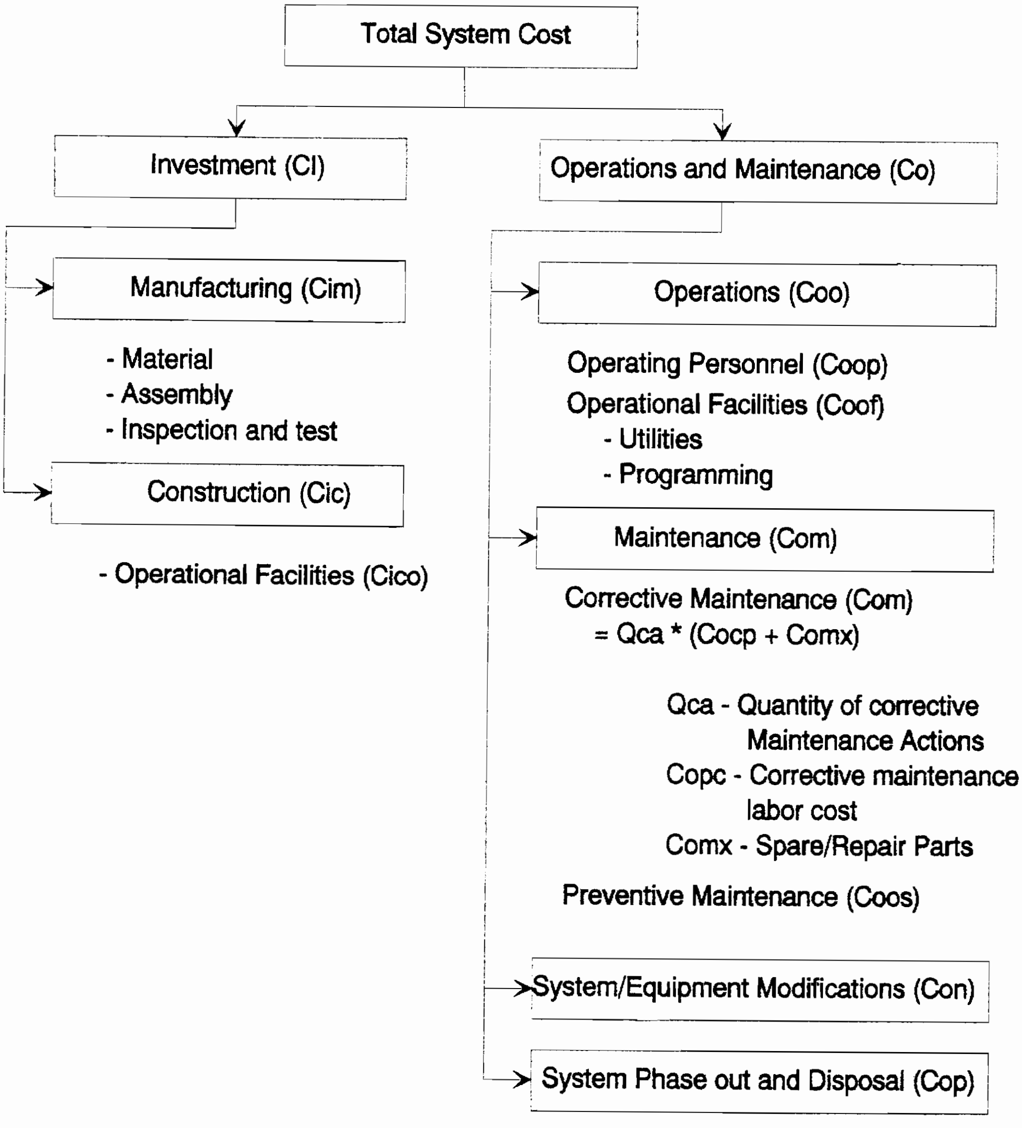

Figure 11. Cost Breakdown Structure

An estimate of the investment cost is a important consideration to determine that the system is within the boundaries established in the operational requirements. Operational and maintenance costs are an important consideration over the life cycle of the system. They are also used as a means to compare the various alternatives in terms of their performance over the system life cycle of 10 years.

Operating costs include utilities, required operating personnel, and monthly programming costs. The main utility would be supplying power to the equipment. Operating personnel costs include, at most, one individual to periodically visually inspect and monitor the common area equipment. Programming costs are dependent on the system and the number of channels required. It was assumed in most cases that a monthly cost of $30 per homeowner was reasonable for a basic package of programming which offers the required number of channels as listed in the operational requirements.

Maintenance costs are a combination of preventive and corrective maintenance costs. It is expected that none of the alternatives will require significant preventive maintenance. The cost incurred due to preventive maintenance actions is, therefore, assumed to be accounted for in the cost of any required operating personnel. The corrective maintenance cost is a combination of the Qca, Cocp and Comx. An assumed cost of $300.0 is used to account for the Cocp and Comx costs for alternative number two. An assumed cost of $1000.00 is used to account for the Cocp and Comx costs for alternative number three since the systems purposed are of a higher complexity. The Qca is calculated from the total number of hours the system is in use(To), which is equal to 87600 hours (10 years) and an estimated system MTBF.

$$Qca = To / MTBF_{system} \qquad (2)$$

A system MTBF is calculated by combining the individual component MTBF values throughout the system. Individual component MTBFs can be combined using the relationship between a component MTBF and reliability which is defined in Eq. 3 as

$$R(t) = \exp(-t/MTBF) \quad (3)$$

The factor t in Eq. 3 is a usage time. Components in a system may have different usage times over the same period. For instance, over a one year period a component maybe in use constantly which would constitute a usage time of 8760 hours or it may be used periodically which would result in a smaller usage time. In all cases, component reliabilities may be combined either in series or in parallel. All components required for the systems full operation are considered in series, redundant networks are considered in parallel.

If components are in series, then the system reliability is found by multiplying the individual component reliabilities. For example, if a system was made up of three components, A, B and C, the system reliability would be equal to

$$R_{system} = R_A * R_B * R_C \quad (4)$$

A system MTBF is then derived from the system reliability. The system MTBF is an important parameter used as a measure of system effectiveness and a means for estimating corrective maintenance costs as

$$MTBF_{system} = \frac{-t}{\ln(R_{system})} \quad (5)$$

If the usage time is the (t) is the same for all components in the system, then the MTBF for the system may be related to the MTBF for the components by combining

Eq. 3 through 5 to obtain

$$1/MTBF_{system} = 1/MTBF_i + 1/MTBF_{i+1} \ldots + 1/MTBF_n \qquad (6)$$

4.1 FEASIBLE ALTERNATIVE #1

4.1.1 System Description

TCI cable accesses local television from broadcast towers in Roanoke and Bedford, VA, along with satellite programming from analog C-band satellite systems. The television stations are then distributed via a cable network to the community. Each individual homeowner typically requires a converter box in their home which serves to select and de-scramble pay television channels.

4.1.2 Life Cycle Cost Estimation

The cost to the community for cable television includes an installation and monthly programming fee. Maintenance or operational costs are not applicable in this case since that would be the responsibility of the cable company.

TCI cable, like any other cable company, works by trunking the signal from its main distribution center throughout its servicing area. A cable company is able to service an area if the area is within "range" of the main distribution center. The range is determined by the length of cable and amount of amplification that must be placed in the cable lines to extend service. There is, of course, a practical limit to how far from the main distribution center TCI cable can carry the signal. TCI has estimated that the community is within range of cable service, however, there are stipulations as to whether or not TCI will extend service.

If a community is within "range" of the cable company, then there are a number of standards used to determine the cost and feasibility of extending service. The cost to the cable company to extend service is approximately $13,000 per mile. For the cable company to extend service free to a community and absorb the installation cost the community must be a minimum of 40 houses per square mile. If the community is not large enough to have cable extended for free, it may elect to pay for having service extended. In this case the cost to the community would be 75 cents per foot starting 300 ft from existing service to the community location. The cable company would absorb the remainder of the installation cost(Hoyle, 1995).

The Twin Meadows community is not large enough to meet the first condition and have cable service extended for free. The community may choose to pay to have cable service extended at an estimated cost to the community of $59,000. This translates into a cost per homeowner of $2950. The average cost for a typical programming package is approximately $24 per month per homeowner.

4.2 FEASIBLE ALTERNATIVE #2

The three system configurations considered under feasible alternative #2 are an analog C-band system combined with a terrestrial antenna and two types of digital Ku-band systems combined with a terrestrial antenna. Fig. 9 illustrates the set-up of these systems. The following system description applies to all three systems.

4.2.1 System description

A terrestrial type antenna along with an antenna tower is set up to receive local programming. The output signal from the terrestrial antenna is routed to the individual entertainment system via coax cable. A parabolic antenna is set up for receiving satellite programming. In the case of a C-band system the antenna will need to be aligned to receive a desired satellite. The signal from the satellite antenna is input to a satellite LNB(low noise block converter). The satellite LNB transforms the output signal from the antenna down to the first IF frequency which would range from 950 to 1450 MHz. The output from the satellite LNB is routed to a satellite receiver in the home. The satellite receiver tunes, demodulates, and selects individual stations. The output of the satellite receiver is input to the entertainment system.

4.2.2 Estimated Life cycle Costs

Table 7 lists estimated initial equipment and installation costs for an analog C-band system. Table 8 lists estimated initial equipment costs for both Ku-band systems. The first Ku-band system in Table 8 would be purchased and provide service from DirecTV or USSB. The second system would be leased and provide service from PRIMESTAR. The initial cost estimates were obtained from a number of sources as follows. The tower cost was based on information from ROHN, a Ohio based company specializing in antenna towers, Radio Shack which distributes terrestrial antennas and amplifiers and Scientific Atlanta which distributes a wide range of satellite and terrestrial products.

Maintenance costs are derived from the system reliability. The system reliability is calculated by combining all the individual component reliability values in series. The components which make-up this system were illustrated in Fig. 9. The individual MTBF values for each component illustrated in Fig. 9 are given in Table 9. Table 9 also show the expected total operating hours for each component over the life cycle of the system.

The following calculations show how the maintenance cost is determined for this particular alternative. The calculations are representative of all further maintenance cost calculations for the other alternatives and the various options.

Table 7. Equipment and installation cost estimates for an individual C-band system combined with a terrestrial antenna

		C-band System and Terrestrial Antenna		
System	Units	Type	Equipment	Installation
Local	1	Tower	$ 62	$ 60
	1	Terrestrial Antenna	$ 100	
	1	Amplifier	$ 30	
Satellite	1	Satellite Antenna	$ 400	$ 60
	1	Satellite LNB	$ 120	
	1	Receiver	$ 700	
Distribution	50 ft	Coax Cable	$ 12.5($.25/ft)	
Totals(Cost per Homeowner)			$1424.50	$ 120

Table 8. Equipment and installation cost estimates for two Ku-band systems combined with a terrestrial antenna.

Ku-band System #1 and Terrestrial Antenna

System	Units	Type	Equipment	Installation
Local	1	Tower	$ 62	$ 60
	1	Terrestrial Antenna	$ 100	
	1	Amplifier	$ 30	
Satellite	1	Satellite Antenna	$ 50	$ 20
	1	Satellite LNB	$ 120	
	1	Receiver	$ 530	
Distribution	50 ft	Coax Cable	$ 12.5($0.25/ft)	
Totals(Cost per Homeowner)			$ 904.50	$ 80

Table 8(continued). Equipment and installation cost estimates for two Ku-band systems combined with a terrestrial antenna.

Ku-band System #2 and Terrestrial Antenna

System	Units	Type	Equipment	Installation
Local	1	Tower	$ 62	$ 60
	1	Terrestrial Antenna	$ 100	
	1	Amplifier	$ 30	
Satellite	1	Satellite Antenna,LNB and Receiver	$ 200	$ 20
Distribution	50 ft	Coax Cable	$ 12.5($0.25/ft)	
Totals(Cost per Homeowner)			$ 404.50	$ 80

Table 9. Estimated MTBF values and expected times of operation for the both the C-band, Ku-band and terrestrial antenna systems

Type	MTBF(hours)	Estimated usage over the ten year life cycle(t)
Terrestrial Antenna	175,000	87600 hours
Amplifier	105,000	87600 hours
Satellite Antennas	175,000	87600 hours
Satellite LNB	105,000	87600 hours
Satellite Receiver	87,600	87600 hours

Given the values of the component MTBFs, the system MTBF is calculated from Eq. 6. This calculation assumes all components are in series since all the components are required for the system to fully operate. The product nature of the system for the series connection leads to the equivalent system MTBF calculation given as

$$1/MTBF_{system} = 1/MTBF_{terrestrial\ antenna} + 1/MTBF_{terrestrial\ amplifier} + 1/MTBF_{satellite\ antenna} + 1/MTBF_{satellite\ LNB} + 1/MTBF_{satellite\ receive}$$

$$1/MTBF_{system} = 1/175000 + 1/105000 + 1/175000 + 1/105000 + 1/87600$$

giving a system MTBF of

$$MTBF_{system} = 23{,}871 \text{ hours}$$

This MTBF meets the 7992 hours needed for an availability of 99.9 % with a mean down time of 8 hours calculated in Section 2.14.

The quantity of corrective maintenance actions for the system over its life cycle is calculated from the system MTBF. In this case (To) is equal to 87600 hours or 10 years giving

$$Qca = To / MTBF_{system} = 3.6697$$

The cost of all maintenance actions is determined by multiplying the Qca times $300.0 or $1000.00 which is the assumed cost per maintenance action taking into account a labor rate and replacement parts. The annual maintenance costs are found by dividing the total cost by ten and in the case of alternative number three, the total cost is also divided by 20 to account for the 20 homes. The overall maintenance costs given a value for the system MTBF are summarized in Table 10.

Table 10. Maintenance cost estimates for all system configurations under feasible alternative #2 over a ten year period

	System MTBF (Hours)	**Total Quantity of Maint. Actions Qca**	**Cost per Maint. Action ($)**	**Total Cost of Maint. Actions ($)**
System	23,871	3.669	300.0	1100.70
Annual Maintenance cost per Homeowner				110.07

There are number of considerations under operating costs. The cost of utilities for all systems is estimated at $3.00 per month. The individual systems do not require any operating personnel. Programming costs vary between the systems. A flat rate of

$30 a month is assumed as a reasonable cost to obtain the required amount of programming as listed in the operational requirements. These costs translate into an estimated operating cost of $396.00 for the C-band and purchased Ku-band system. The leased Ku-band system has an additional $10 fee for equipment rental. The total annual operating costs for this system is $516.00

4.3 FEASIBLE ALTERNATIVE #3

4.3.1 SMATV(Satellite Master Antenna Television) System Configuration

The first system configuration involves designing a SMATV(satellite master antenna television) system which is basically a mini-cable company stationed at the housing development. The basic system configuration for this concept is illustrated in Fig. 12. In an SMATV system, all required television stations are received individually and simultaneously through a parallel receiving system at the site of the community shared equipment. The television signal output from the terrestrial antenna and each of the individual channels within the channelized receiver are in the same format as illustrated earlier in Fig. 4.

4.3.1.1 System Description

A terrestrial type antenna is set up to receive local programming and a parabolic antenna is set up for satellite reception. In the case of a C-band system, it requires multiple antennas or one specialty type antenna to simultaneously receive multiple satellites. The output signal from the satellite antenna(s) is input to a satellite LNB(low noise block convert). The satellite LNB transforms the output from the antenna down to the first IF frequency which would range from 950 to 1450 Mhz. The splitter divides the output signal from the satellite LNB into the required number of channels where each channel would represent an individual television station. Each

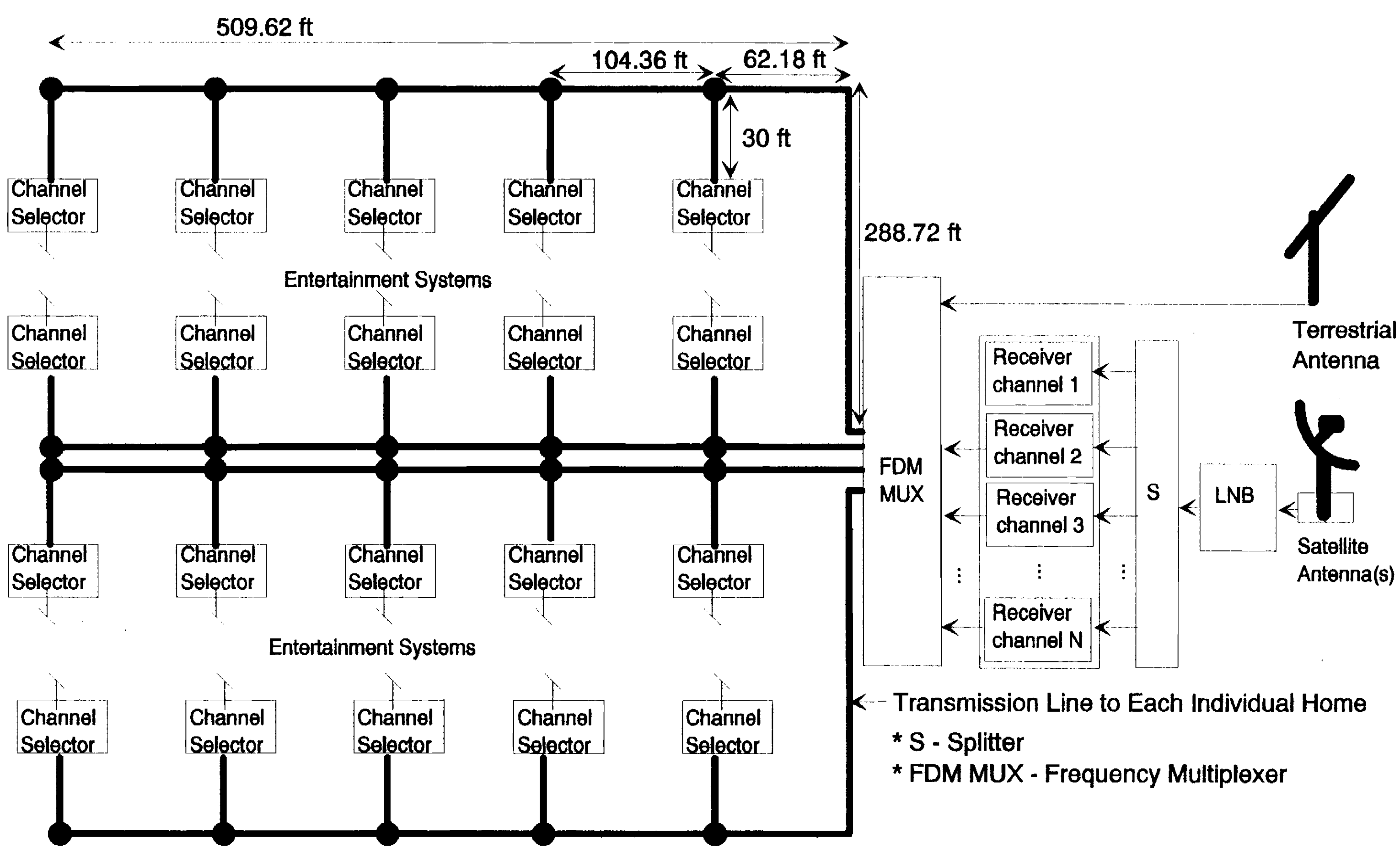

Figure 12. SMATV system applied to the Twin Meadows housing development. A SMATV system applies the concept of a channelized receiver to detect and distribute required television signals

receiver in the channelized receiver system would tune, demodulate and detect each individual station. The modulator would serve two purposes first to translate the received signal to a UHF or VHF channel frequency and then re-modulate the signal so that is conforms to NTSC standards. The output of each modulator goes into a combiner which combines each television station including the output television signal from the terrestrial signal. The terrestrial signal and remodulated satellite signal are in the same format. The output of the combiner goes into the distribution system where the signal is divided and distributed via coax cable to each home. In each home there would be a converter box which selects and de-scramble individual stations before being input to the individual home entertainment systems or directly uses a cable ready television.

4.3.1.2 Life Cycle Cost Estimation

Tables 11 and 12 summarize the major equipment and installation costs for a C-band and a Ku-band SMATV system. The cost estimates were obtained through catalog information from Scientific Atlanta. The "receiver" component in a digital Ku-band system is different then the "receiver" component in an analog C-band system. The receiver costs, however, are similar. The satellite antenna is the main difference between systems.

Maintenance costs are derived from the system reliability. The system reliability is calculated as in Section 4.22, where each component is combined in series to determine an overall system reliability. The reliability block diagram for this system is given in Fig. 13. The components in the system are combined as given in Eq. 7 for the worst case of a single satellite channel.

$$R_{system} = R_{antenna\ system} * R_{distribution} \qquad (7)$$

Table 11. Equipment costs for portions of a C-band SMATV system. The equipment costs where obtained from Scientific Atlanta catalogs.

System	Units	Type	Equipment	Installation
Local	1	Tower	$ 62	$ 60
	1	Terrestrial Antenna	$ 100	
	1	Amplifier	$ 30	
Satellite				
Antennas	4	Satellite Antennas	$ 1200 ($300 Each)	$ 100
	4	Satellite LNBs	$ 480 ($120 Each)	
	3	Amplifiers	$ 150 ($50 Each)	
Channel Receiver	30	satellite receiver	$43000 ($1440 Each)	
	30	modulator	$24000 ($800 Each)	
Distribution	1	Combiner	$ 60	
	27	Splitters	$ 1350 ($50 Each)	
	2616 ft	Community Lines(Coax Cable)	$ 654 ($0.25/ft)	$1308($0.50/ft)
	600 ft	Home distribution	$ 150 ($0.25/ft)	
Home Equipment	20	Converter Box	$ 2000 (100 Each)	
Totals			$73,376.00	$ 1,468.00
Individual Homeowner Cost			$ 3,668.00	$ 73.40

Table 12. Equipment costs for portions of a Ku-band SMATV system. The equipment costs where obtained from Scientific Atlanta catalogs.

System	Units	Type	Equipment	Installation
Local	1	Tower	$ 62	$ 60
	1	Terrestrial Antenna	$ 100	
		Amplifier	$ 30	
Satellite				
Antennas	1	Satellite Antennas	$ 100	$ 100
	1	Satellite LNBs	$ 120	
	3	Amplifiers	$ 150 ($50 Each)	
Channel Receiver	30	satellite receiver	$43000 ($1440 Each)	
	30	modulator	$24000 ($800 Each)	
Distribution	1	Combiner	$ 60	
	27	Splitters	$ 1350 ($50 Each)	
	2616 ft	Community Lines(Coax Cable)	$ 654 ($0.25/ft)	$1308($0.50/ft)
	600 ft	Home distribution	$ 150 ($0.25/ft)	
Home Equipment	20	Converter Box	$ 2000 (100 Each)	
Totals			$71,976.00	$ 1,468.00
Individual Homeowner Cost			$ 3,598.80	$ 73.40

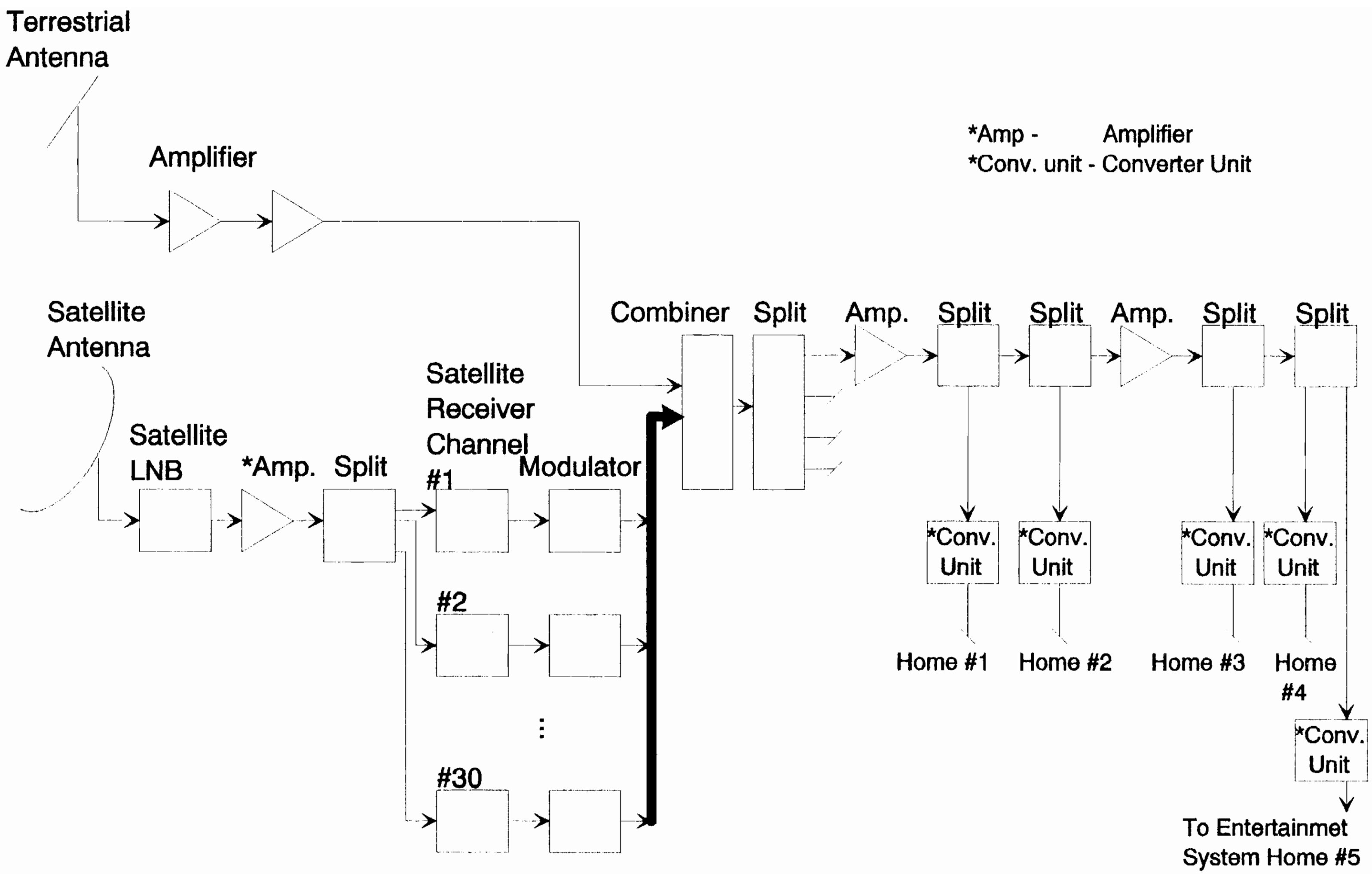

Figure 13. Block diagram of a SMATV Ku or C-band system combined with a terrestrial antenna. The block diagram of the system is used to calculated an estimated system reliability

$$R_{system} = (R_{ant} * R_{amp} * R_{split} * (R_{rec} * R_{rec})) *$$
$$(* R_{comb} * R_{split} * R_{amp} * R_{split} * R_{split} * R_{amp} * R_{split} * R_{split} * R_{rec})$$

where ant = Satellite antenna

amp = Satellite LNB, In-line Amplifiers

rec = Satellite Receivers or Modulators

comb = Combiner

split = Splitter

Table 13 summarizes the MTBF values for the components in the system. Table 14 summarizes the maintenance costs for this alternative.

Table 13. Estimated MTBF values and expected times of operation for the SMATV C-band, Ku-band and terrestrial antenna systems

Type	MTBF(hours)	Estimated usage over the ten year life cycle(t)
Terrestrial Antenna	175,000	87600 hours
Amplifier	105,000	87600 hours
Satellite Antennas	175,000	87600 hours
Satellite LNB	105,000	87600 hours
Receiver/Modulator	87,600	87600 hours
Splitter/Combiner	175,000	87600 hours
Satellite Receiver	87,600	87600 hours

There are a number of considerations under operating costs. The utilities would include the cost for the homeowner's personal equipment plus the community equipment. The cost for either is assumed to be $36.00 per year. The utilities cost to the homeowner is then $36.00 plus 1/20 of the community utility cost as given.

Utilities Cost = $36.00 + $1.80 = $37.80

Table 14. Overall system maintenance cost for the SMATV system configurations under alternative #3 over a ten year period

	System MTBF (Hours)	Total Quantity of Maint. Actions Qca	Cost per Maint. Action ($)	Total Cost of Maint. Actions ($)
System	9213.85	9.507	1000.0	9507.43
Annual Maintenance cost per Homeowner				47.54

The system does not require any operating personnel but does require an individual to periodically inspect the equipment. The cost for this individual is estimated annually at $24.00 per homeowner. Again, a flat rate of $30 a month is assumed as a reasonable cost to obtain the required amount of programming as listed in the operational requirements. This all translates into a total annual operating cost of $421.80 per homeowner.

4.3.2 Shared Antenna Community Television (SACT) System

In the second configuration, illustrated in Fig. 14, the community shares some of the basic components of a receiving system including a terrestrial and satellite antenna system. The satellite receiving equipment is in each individual home.
For this configuration only a digital Ku-band system is considered. It is not clear that a practical system could be developed utilizing a C-band antenna system. The output of a C-band antenna could be shared. However, the off-the-shelf C-band home receivers are only capable of simultaneously processing 24 channels or one satellite.

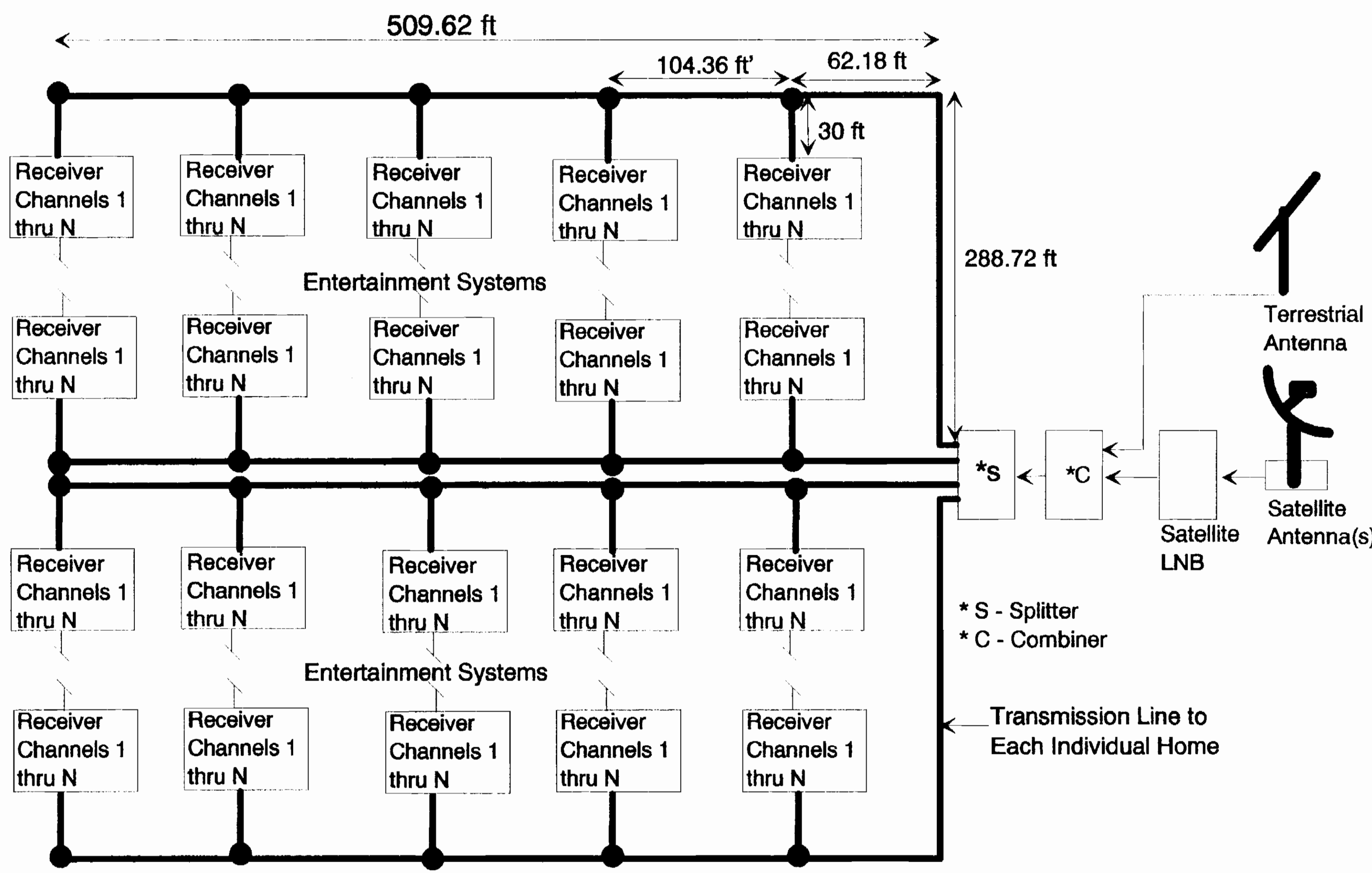

Figure 14. A SACT system configuration for the Twin Meadows housing development

The community would, therefore have to rotate the antenna which would not be practical or set up a system similar to what was described with the SMATV systems.

4.3.2.1 System Description

A terrestrial type antenna is set up to receive local programming and a parabolic antenna is set up for satellite programming. The output signal from the satellite antenna is input to a satellite LNB. The satellite LNB transforms the output from the antenna down to the first IF frequency which ranges from 950 to 1450 MHz. The output signal from the terrestrial antenna and Satellite LNB is combined at this point and input to the distribution system. From the combiner, the signal is split and redistributed to the each homeowner. In each home the signal is again split. One lead goes into a satellite receiver for further processing of the satellite signal. The satellite receiver tunes, demodulates and detects individual satellite stations. The output from the satellite receiver is input to the entertainment system along with the lead from the terrestrial antenna.

4.3.2.2 Life Cycle Costs Estimation

Table 15 estimates equipment costs for a SACT Ku-band system. Again, maintenance costs are derived from the system reliability. The system reliability is calculated as in Section 4.22, where each component is combined in series to determine an overall system reliability. The reliability block diagram for this system is given in Fig. 15. The components in the system are combined as

$$R_{system} = R_{antenna\ systems} * R_{distribution} \quad (8)$$

$$R_{system} = (R_{ant} * R_{amp} * R_{amp}) * (*R_{comb} * R_{split} * R_{amp} * R_{split} * R_{split} * R_{amp} * R_{split} * R_{split} * R_{rec})$$

Table 15. Estimated equipment costs for a SCAT KU-band system under feasible alterative #3

System	Units	Type	Equipment	Installation
Local	1	Tower	$ 62	$ 60
	1	Terrestrial Antenna	$ 100	
	1	Amplifier	$ 30	
Satellite	1	Satellite Antennas	$ 50	$ 60
	1	Satellite LNBs	$ 120	
	3	Amplifiers	$ 150 ($50 Each)	
Distribution	1	Combiner	$ 60	
	27	Splitters	$ 1350 ($50 Each)	
	2616 ft	Community Lines(Coax Cable)	$ 654 ($0.25/ft)	$1308($0.50/ft)
	600 ft	Home distribution	$ 150 ($0.25/ft)	
Home Equipment	20	Satellite Receiver	$10600 (530 Each)	
Totals			$13,326.00	$ 1,428.00
Individual Homeowner Cost			$ 666.30	$ 71.40

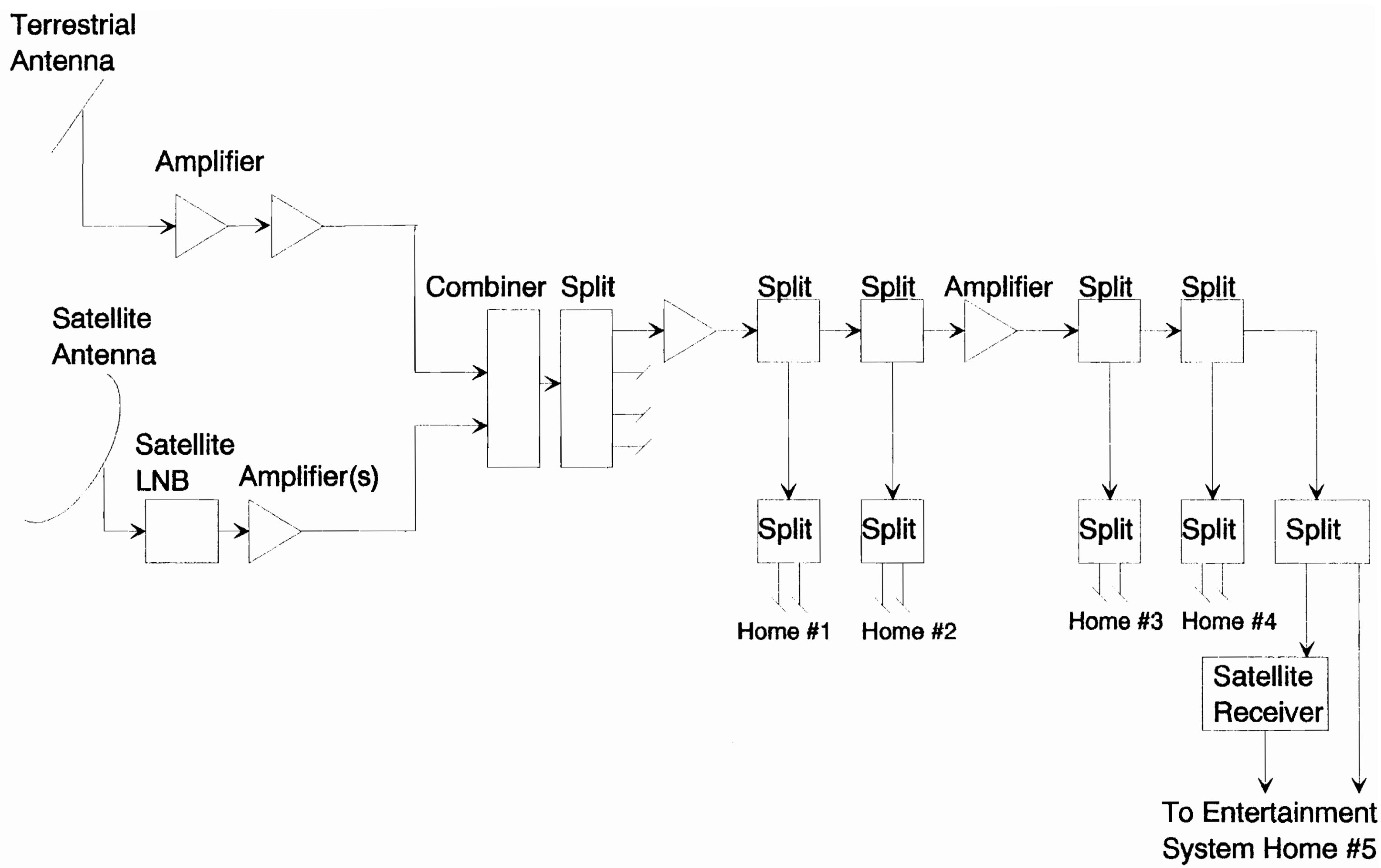

Figure 15. Block diagram of a SACT Ku-Band System combined with a terrestrail antenna. The block diagram of the system is used to calculated an estimated system reliability.

where ant = Satellite antenna

amp = Satellite LNB, In-line Amplifiers

rec = Satellite Receiver

comb = Combiner

split = Splitter

The MTBF values for each component in the path were given previously in Table 13. The results of the reliability study are used to derive an overall system maintenance cost as summarized in Table 16.

Table 16. Estimated maintenance costs for SACT Ku-Band system under feasible alternative #3 over a ten year period

	System MTBF (Hours)	Total Quantity of Maint. Actions Qca	Cost per Maint. Action ($)	Total Cost of Maint. Actions ($)
System	11,171.8	7.84	1000.0	7841.14
Annual Maintenance cost per Homeowner				39.21

The operating costs are estimated to be the same for the SACT system as the two previously mentioned SMATV systems. Thus, annual operating costs for the SACT systems is $433.27.

5.0 DETAILED DESIGN OF A SHARED ANTENNA COMMUNITY TELEVISION (SACT) Ku-BAND SYSTEM

The preliminary analysis process in Chapter 4.0 justified the selection of a system configuration based on major system tradeoffs including cost. The design phase in this chapter examines the selected alternative in technical terms and develops a design based on the technical requirements or main technical performance measures. Furthermore, the analysis of the technical requirements in this section provides more of a justification for the various hardware components which were identified earlier in the preliminary analysis.

The technical performance parameters included minimum standards for the signal level, signal quality and signal reliability at the input to each individual homeowner entertainment system. This analysis traces the input satellite and terrestrial signals through the receiving system and estimates the signal level and quality at various stages and test points. The stages and test points are illustrated, in part, in Fig. 16. In the case of the satellite signal, it is traced to the input of the individual home satellite receiver. It is assumed in this report that if the specifications for the signal level and signal quality are met for the home satellite receiver then the specifications are met for the satellite receiving system. Also included in this section is a discussion on interference and how that may effect the signal level and quality.

5.1 Signal Input Power and the Signal to Noise ratio

This section examines the input power for the satellite and terrestrial portions of the system separately. This is because a different approach is used to determine good estimates for the input power levels. In both cases the input power and noise level is what is seen at the output of the antenna systems as illustrated in Fig.16.

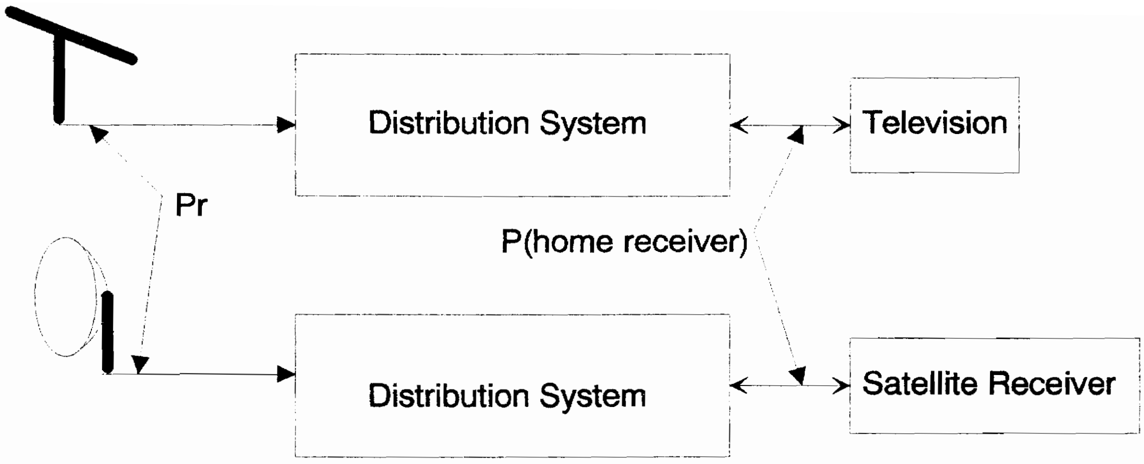

Figure 16. Illustration of where the input power levels to the system and input power levels to the receiver units are referenced

Eq. 9 represents the power received at the output of the satellite antenna taking into account the transmit power from the satellite, transmit losses, the gain of the receiving antenna and other system losses. Each term in this equation is discussed in detail to give a best estimate of the power received.

$$Pr = EIRP_t - L_p - L_a + G_r - L_r \quad \text{(dBW)} \tag{9}$$

$EIRP_t$= Satellite Transmitted Effective radiated power

L_p = Path Loss

L_a = Atmospheric Loss

G_r = Receive Antenna Gain

L_r = Feed and polarization losses

The effective isotropic radiated power (EIRP) accounts for the satellite's transmit power, antenna gain and losses. The EIRP value used in the calculations is the transmit power per-channel. All power levels discussed throughout this section are referred to in a per-channel basis. Appendix B gives a listing of various satellite EIRPs.

$$EIRP_t = 10\log(P_t) + G_t(dB) \qquad (dBW) \qquad (10)$$

P_t = Transmitter power

G_t = Transmitter antenna Gain

Path loss(Lp) accounts for energy loss as the transmitted signal spreads out as an electromagnetic wave away from the source of transmission. Path loss is dependent mainly on the physical distance between the transmitter and receiver.

$$Lp = 20 \log (4*pi*R / \lambda) \qquad (dB) \qquad (11)$$

R = Distance from the transmitter to receiver(m)

λ = wavelength (m)

The distance(R) traveled by the electromagnetic wave is assumed at 39,000 km for the satellite systems. This distance is a standard for satellite systems placed in geosynchronous orbit (Pratt et al, 1986). The smallest wavelength (λ) is equal to 0.02362 which is the speed of light(c) divided by the highest transmit frequency of 12.7 GHz. Given the distance R and the wavelength, the path loss is equal to 206.34 dB.

Atmospheric loss(La) accounts for energy lost due to atmospheric absorption.

There are number of phenomena which cause absorption, most of these phenomena relatively unimportant at most commercial frequency bands. The most important factor is absorption due to precipitation or in particular rain. The attenuation is zero in clear weather, but can be very significant in heavy rain. A frequency of 10 GHz is typically used as the cutoff above which rain has a significant effect on the system. This is applicable to the digital Ku-band systems which operate at around 12 GHz, but not applicable to the terrestrial signals.

There are a number of models which can be used to predict atmospheric attenuation. This report uses the SAM model(Pratt et al, 1986) to predict attenuation as a function of rain rates(R) as given in Eq.12 and 13. Eq. 12 is for regions in which the rain rates fall below 10 mm/h and Eq.13 is for regions where the rain rates exceed 10 mm/h. For R < 10 mm/h

$$A(P) = a\,[R]^{b} L \quad \text{dB} \tag{12}$$

and for R > 10 mm/h

$$A(P) = a\,[R]^{b}\left[\frac{1-\exp[-\gamma b(\ln(R/10))\,L\cos(El)]}{\gamma b(\ln(R/10))\cos(El)}\right] \quad dB \tag{13}$$

R(P)	=	Rain Rate as a percentage of time in (mm/h)	
a	=	$4.21 \times 10^{-5} f^{2.42}$,	$2.9 <= f <= 54$ GHz
		$4.09 \times 10^{-5} f^{0.69}$,	$54 <= f <= 180$ GHz
b	=	$1.41 f^{-0.0779}$,	$8.5 <= f <= 25$ GHz
		$2.63 f^{-0.272}$,	$25 <= f <= 164$ GHz
f	=	Satellite Transmit Frequency (GHz)	
L	=	Path Length (km) of rain	
γ	=	1/22 (empirical quantity)	

The path length(L) between the transmitter and receiver is dependent on a number of other factors which are illustrated in Fig. 17.

$$L = (He - Ho) / \sin (EL) \qquad Km \qquad (14)$$

He = Effective Storm Height (km)

Ho = Height of the receiving antenna system above sea level (km)

EL = Elevation Angle of the Receiving Antenna System (degrees)

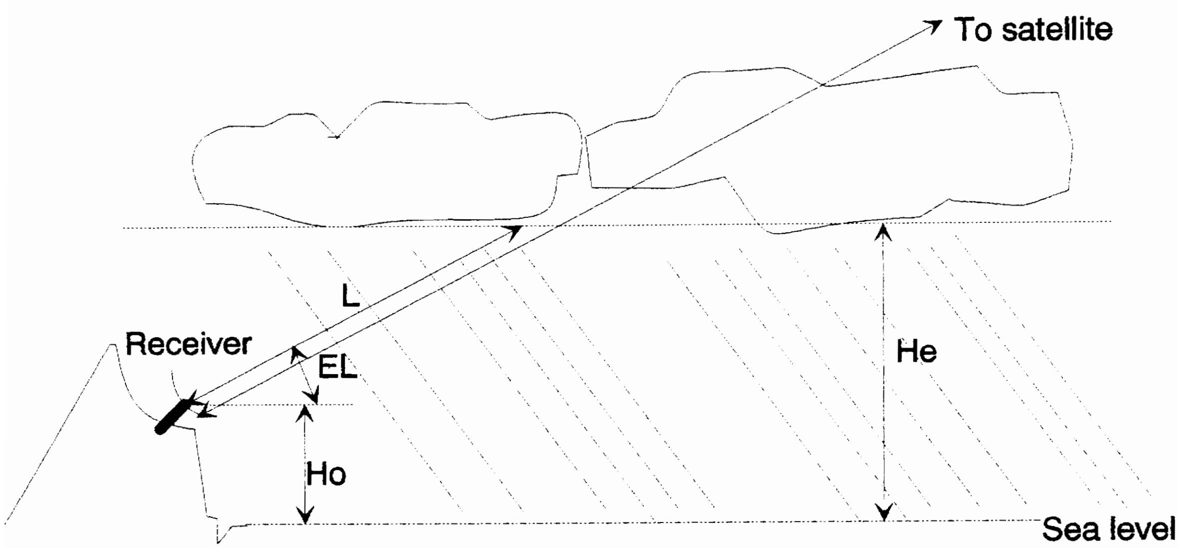

Figure 17. Geometry of the rain attenuation problem as used in the SAM model. He is called the storm height and Ho is the earth station's elevation above sea level (Pratt et al, 1986)

The factor He is dependent on the rain rate and a factor Hi. Hi is the height where the temperature reaches zero degrees. It is called the zero degree isotherm. For a rain rate of R <= 10 mm/h

$$He = Hi,$$

and for R > 10 mm/h

$$He = Hi + \log(R/10)$$

The factor Hi is estimated from the location of the receiving system in terms of degrees latitude Xe. For a latitude |Xe| <= 30 degrees,

$$Hi = 4.8$$

and for |Xe| >= 30 degrees,

$$Hi = 7.8 - 0.1|Xe|$$

The rain rate in a region depends on location. Fig. 18 divides the United States into various regions which experience similar rain rate patterns. Table 17 summarizes the rain rates in each region as a percentages of time. Twin Meadows, which is in South-Central Virginia, falls in area K of Fig. 18. Region K has a rain rate which is less than 2 mm/h, 99 percent of the time. This makes Eq. 12 applicable to the region.

Given the rain rate and a number of other constants, the attenuation factor can be calculated. The other constants required for Eq. 12 include f, Ho, Xe and El. The frequency is taken at 12.7 GHz. The height of the receiving system above sea level(Ho) is estimated at 0.640 km(Pratt). The antenna is pointed at an elevation angle(EL) of 42 degrees to access the satellite systems. The location of the community is estimated at a latitude(Xe) of 37.2 degrees. All these factors equate to a path length(L) of 5.14 meters and an overall attenuation factor of 0.1803 dB.

The Gain(Gr) of the receiving antenna is related to the effective area of the antenna and the satellite transmit frequency by Eq. 15.

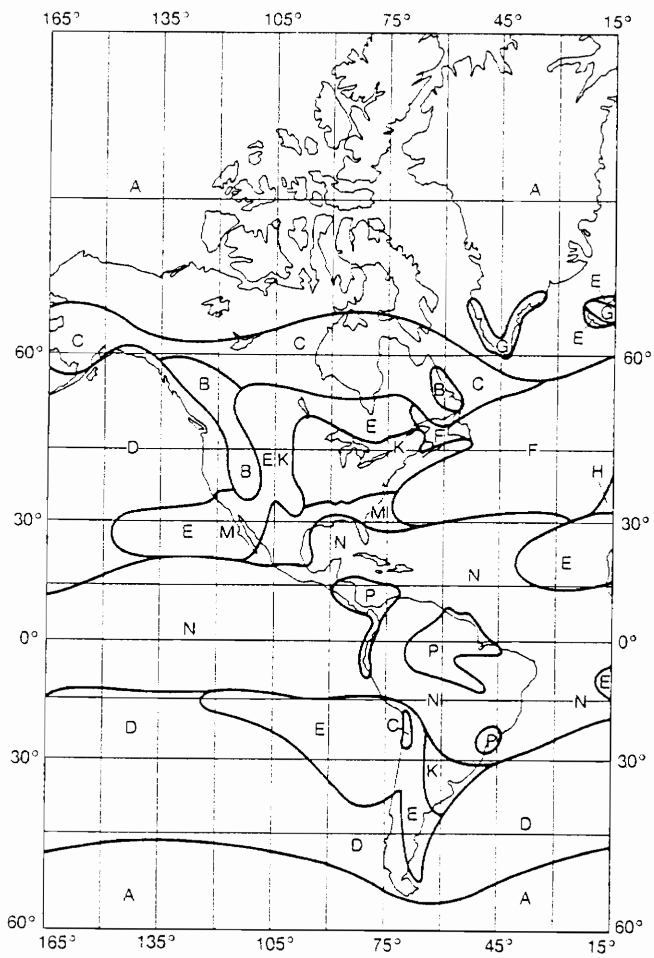

Figure 18. "CCIR rain regions in the Western Hemisphere. (Reprinted with permission from International Radio Consultative Committee(CCIR), Recommendations and Reports of the CCIR, 1982, Volume V, Propagation in Non-Ionized Media, International Telecommunications Union, Geneva, Switzerland, 1982"(Pratt et al, 1986)

Table 17. "Cumulative Rain Rate Statistics for the CCIR Rain Climate Regions. International Radio Consultative Committee(CCIR), Recommendations and Reports of the CCIR, 1982, Volume V, Propagation in Non-Ionized Media, International Telecommunications Union, Geneva, Switzerland, 1982, Reprinted with permission of the CCIR". (Pratt et al, 1986)

Percentage of time (%)	Rainfall Intensity Exceeded (mm/h)													
	A	B	C	D	E	F	G	H	J	K	L	M	N	P
1.0	—	1	—	3	1	2	—	—	—	2	—	4	5	12
0.3	1	2	3	5	3	4	7	4	13	6	7	11	15	34
0.1	2	3	5	8	6	8	12	10	20	12	15	22	35	65
0.03	5	6	9	13	12	15	20	18	28	23	33	40	65	105
0.01	8	12	15	19	22	28	30	32	35	42	60	63	95	145
0.003	14	21	26	29	41	54	45	55	45	70	105	95	140	200
0.001	22	32	42	42	70	78	65	83	55	100	150	120	180	250

$$Gr = 10 \log \left(\frac{4 \cdot pi \cdot Ae}{\lambda^2} \right) \text{ dB} \qquad (15)$$

Ae = Effective area of the receiver antenna

λ = wavelength (speed of light/frequency)

The effective area(Ae) of an antenna system is the physical area of the antenna dish multiplied by an aperture efficiency factor. The physical area of the small satellite dishes with an antenna diameter of 18 inches(0.4573 meters) is 0.1642 square meters. Assuming an efficiency for the antenna system of 65 %, the effective area of the antenna would be equal to 0.1067 square meters. Thus, the overall gain of the antenna, given a transmit frequency of 12.7 GHz is estimated to be equal to 33.79 dB

To account for additional receiver losses(Lr) which would realistically be in the system, a factor of -1.5 dB is included in the calculations. This factor accounts for miscellaneous losses due to the antenna feed and polarization mismatches.

Eq. 16 represents the noise power seen at the input to the system. The noise power is determined from Boltzsmann's constant, the antenna noise temperature and the system bandwidth. The bandwidth for the Ku-band systems is approximately 27 MHz and the worst case antenna noise temperature is assumed at 300 K, giving a noise power of -129.52 dBW.

$$N = 10 \log(K \; Ta \;\; B) \quad (dBW) \qquad (16)$$

K = Boltzsmans Constant = -228.6 dBW/K/Hz

Ta= Antenna Noise Temperature

B = System Bandwidth

The signal to noise ratio is the difference between the received power(Pr) given in Eq. 9 and the noise power(N) given in Eq. 16. The value for the signal to noise ratio in this case is given in Table 18 which summarizes all the calculations made for Eq. 9. The process of finding the input power and noise level is called the down-link budget for a satellite system.

The input power and signal to noise ratio present at the input to the terrestrial system are described by the radar equation in Eq. 9. However, a different approach was taken in analyzing the terrestrial system to ensure a better estimate.

Table 18. Satellite Down-link Input Power and Noise Budget for a Typical Digital Ku-Band System

Satellite EIRP =	60 dBW
Path Loss (Lp)	
Path length(R)	39,000 Km
Frequency(f)	12.7 Ghz
Wavelength ($\lambda = c/f$)	0.02362 m
Lp =	-206.34 dB
Atmospheric Loss (La)	
Maximum attenuation due to rain	
La(max) =	-0.1803 dB
Receiver Gain (Gr)	
Receiving Antenna Area	0.1642 m^2
Receiving Antenna Efficiency (η)	65 %
Wavelength squared (λ^2)	0.00056 m^2
Gr =	33.79 dB
Polarization and Feed losses (La)	
Polarization Loss	-0.5 dB
Feed losses	-1.0 dB
La(max) =	-1.5 dB
Received Power(Pr) 99% of the time = - 114.23 dBW	
Noise Power Budget(N = kTaB)	
Boltzsmans Constant(k)	-228.6 dBW/K/Hz
Receiving Antenna Noise Temp.(Ta)	300 K
Channel Bandwidth(B)	27 Mhz
Noise Power(N) = -129.52 dBW	
Signal to Noise ratio(S/N) = 15.29 dB	

Satellite systems have the luxury of transmitting in free space while terrestrial systems on the other hand must propagate over the earth's terrain. The earth's terrain will cause additional losses in the propagated signal. Furthermore, a ground based antenna system is limited by what is called the radar horizon. The radar horizon depends on the height of the transmitting and receiving antennas as is given in Eq. 17. Past the radar horizon, the transmitted signal is reduced significantly (Skolnik & Merrill, 1990).

$$\text{Radar horizon} = 130\,(\sqrt{\text{Height}_{\text{transmitter}}} + \sqrt{\text{Height}_{\text{receiver}}})\ \text{Km} \qquad (17)$$

Table A-2 in Appendix A lists transmitter antenna heights for the channels of interest. Twin Meadows is approximately 121 km from the transmitters on Poor Mountain, 100 km from the transmitter on Flat Top Mountain and 73 Km from the transmitter on Thaxton Mountain. The antenna at Twin Meadows will be placed at a height of 12 meters. In general, it is best to place the receiving antenna as high as possible to avoid horizon problems as well as other interference. Forty feet is chosen as a reasonable height. Given these parameters the radar horizon for the transmitters at Poor Mountain would be 113 km(channels 7 and 10). The radar horizon for the transmitter at Flat Top Mountain is 104 km (channel 21) and the radar horizon for the transmitter at Thaxton Mountain is 113 km (channel 13). The conclusion from these calculations is that all the channels are accessible, although channels 7 and 10 are on the fringe.

This alternative approach towards calculating a received power is obtained by rearranging terms in Eq. 9. The terms in the equation for the terrestrial system are the incident power density(S), effective area(Ae) of the receiving antenna and system losses. In the case of the terrestrial portion of the system the losses are included when an estimate of the field strength is made.

$$Pr = S * Ae * Losses \quad \text{(Watts)} \tag{18}$$

$$S = \frac{(Pt*Gt)}{4\pi R^2}$$

$$Ae = \frac{Gr*\lambda^2}{4\pi}$$

The incident power density of the transmitted signal is specified at the point of the receiving antenna system. This density is estimated by taking into account losses due to the terrain using estimates determined by the Federal Communication Commission (FCC). Figs. 19 and 20 are used to determine the appropriate density. The curves provide estimates of field strengths given transmitter height and transmitter EIRP values accounting for an average terrain. Fig. 19 illustrates curves for channels 7-13 and Fig. 20 for channels 14-69. The steps for how the received power (Pr) is calculated, as well as, an example of how these charts are used is given as follows:

1. Determine the distance in km to the site of the receiver in reference to the transmitter and locate that curve in Fig. 19 or 20.
2. Follow that curve until it intersects with the transmitter height as shown along the bottom of the graph.
3. Draw a horizontal line to the left hand side of the graphs to get the "Field strength in dB above 1 uv/m for 1 kW EIRP". This is the relative field strength at the site of the receiving antenna. The power density may then be obtained by adding the relative field strength in dB to -145.8 dBW, the strength of 1uv/m. Add this number to the Transmitter EIRP in dBkW for the total density.

The following is an example of the calculations for channel 7. The transmitter for channel 7 is located on Poor Mountain which is 121 km from the site of the

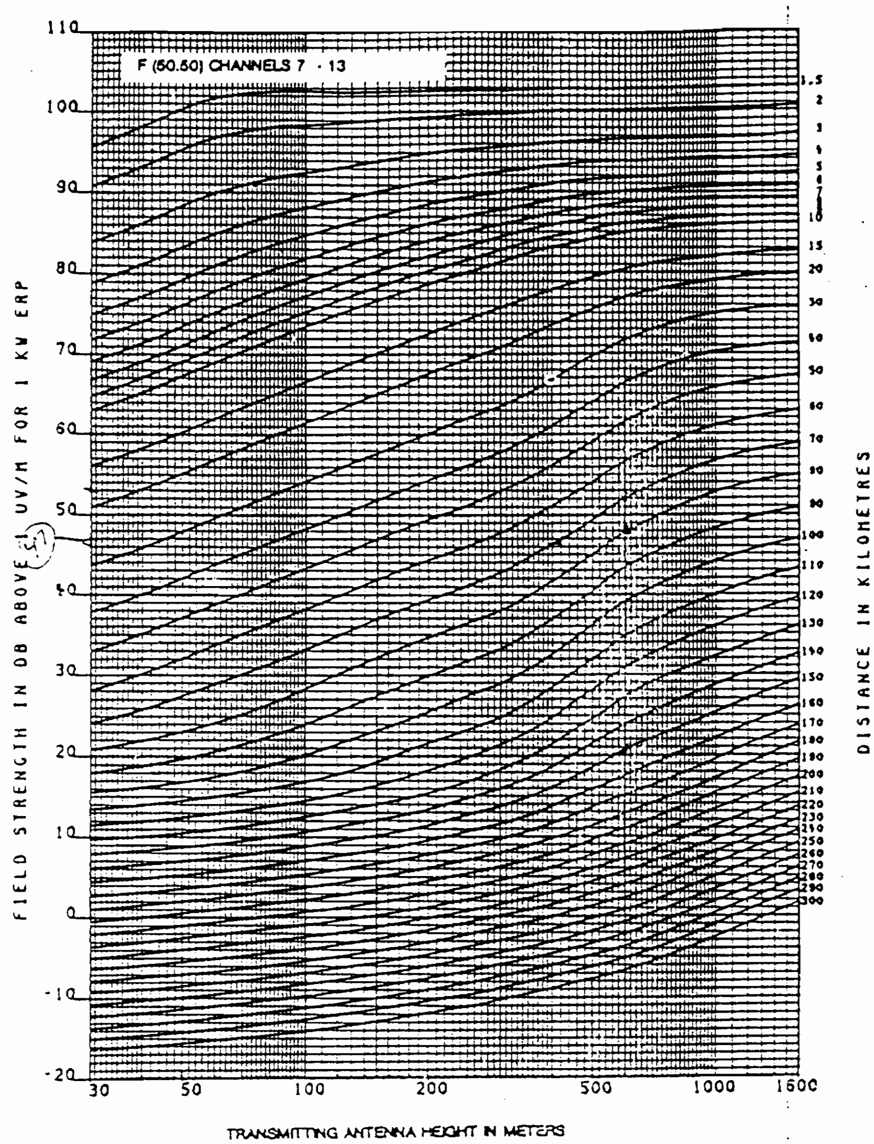

Figure 19. FCC regulations showing the attenuation due to a 50 % terrain for channels 7 -13 (Telecommunication., 1994).

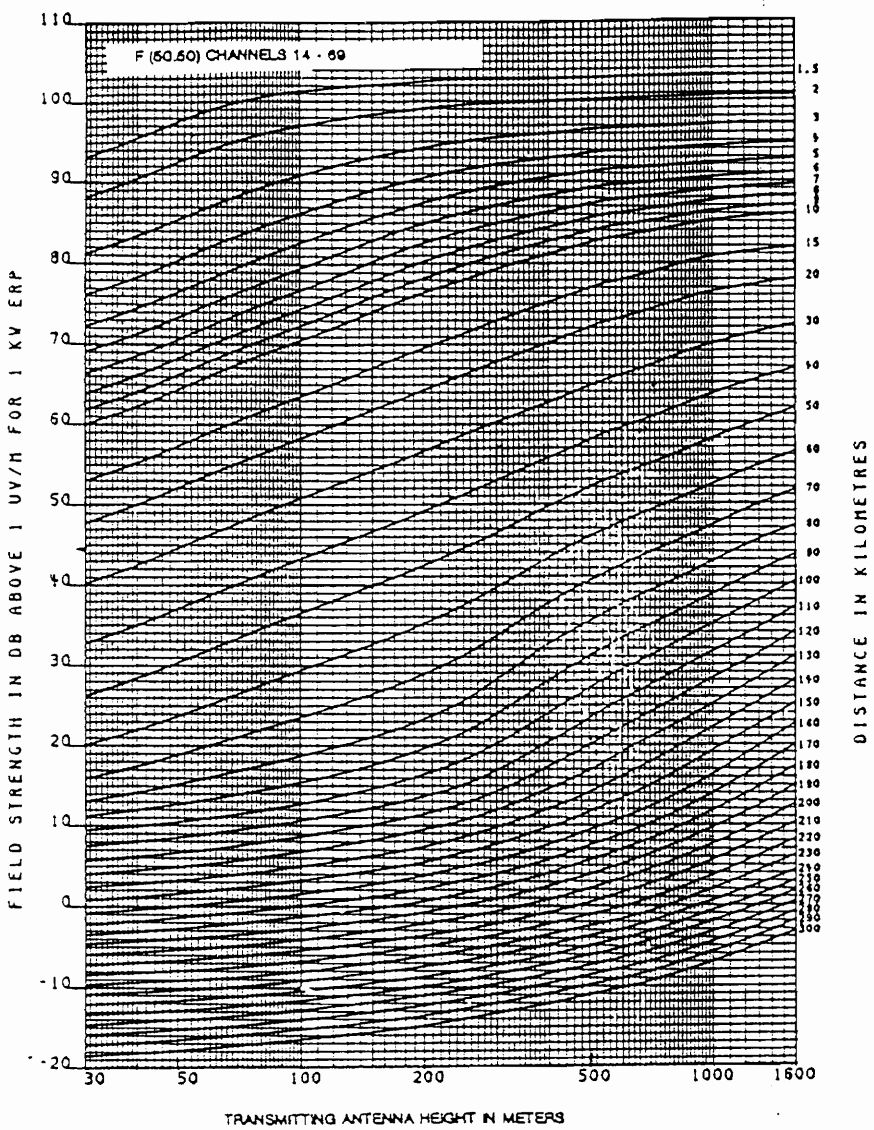

Figure 20. FCC regulations showing the attenuation due to a 50 % terrain for channels 14 -69 (Telecommunication, 1994).

housing community. Locate the curve from the right hand side of the graph which represents 121 km. In this case the 120 km curve is used as a good estimate. Find where the curve and the transmitter antenna height intersect. The height of the transmitter above average terrain in this case is 609 meters. Draw a line horizontally to the left of the graph to find the "field strength in dB above 1 uv/m for 1 KW ERP", in this case the value is 31 dB . Add to the difference value -145.8 dBW and the transmitter EIRP which is 25 dBkW. The result is a field strength of -89.8 dBW/m^2. The transmitter EIRPs are listed in Table A-1 of Appendix A. Table 19 summarizes the estimates for each of the channels of interest.

Table 19. The incident power density (S) of the various channels at the site of the housing community for transmit EIRPs of 25 dBkW and 27 dBkW

Channel	Transmit Antenna Height (meters)	Distance to the Receiver (km)	Difference In field strength (dB)	Field Strength level (dBW/m^2)
7	609.75	121	31	-89.9
10	609.75	121	31	-89.8
13	579.56	73	50	-70.8
21	500.00	100	27	-91.8

The second term in the power equation is the effective area of the receiving antenna(Ae). This is estimated using an assumed gain for the receiving antenna of 8 dB and the corresponding channel frequency. Table 20 shows the calculated effective areas for each channel and the power levels(dBm) seen at the output of the terrestrial antenna using the incident power density values calculated in Table 20.

Table 20. Calculation of the received power at the input to the terrestrial system.

Channel	Frequency (Mhz)	Field Strength (dBm/m^2)	Affective Area(Ae) (dBm^2)	Received Power(Pr) (dBm)
7	180	-59.76	1.45	-58.31
10	198	-59.76	0.62	-59.14
13	216	-40.76	-0.14	-40.90
21	518	-61.76	-7.73	-69.49

Table 2 in Section 2.12 shows what the levels should be if the field strength at the housing site is equal to what is specified by the FCC to be "Grade A" service. Note from Table 20 that 3 out of the 4 channels do not meet the "Grade A" standard even when assuming a receiving antenna gain of 8 dB, but are felt to be at levels which will be acceptable to the community within "Grade B" serviced defined by the FCC.

The noise power is estimated from Eq. 16 as was done earlier for the satellite systems. In the case of the terrestrial system, the antenna temperature is taken at 300 K and the system bandwidth is taken at 6 MHz. This equates to an input noise level for the terrestrial system of -136.04 dBW.

As with the satellite portion of the system, the signal to noise ratio is the difference between the input signal and noise power. In this case, the input signal level ranges from -69.49 dBm to -40.90 dBm. This corresponds to a minimum signal to noise ratio of 36.55 dB and a maximum of 58.31 dB.

5.2 DISTRIBUTION SYSTEM GAIN AND NOISE FIGURE

The distribution portion of the system has a positive and negative affect on the system. The positive effect is that it adds gain to the system which will bring the system up to the required specifications. The negative affect is that it adds noise to the system. This section examines how the distribution system effects the signal and concludes with a suggested detailed system configuration for this alternative.

The distribution portion of the system effects the signal level and signal to noise ratio dependent on its gain and noise figure. The gain of the distribution system is equal to the sum of the individual component gains(in dB). The signal level at the home receiver is equal to the gain of the distribution system added by the input signal as given in Eq. 19

$$P_{home\ receiver}\,(dBW) = P_r\,(dBW) + G_{distribution\ system}\,(dB) \qquad (19)$$

$$G_{distribution\ system} = G_i + G_{i+1} \ldots G_n (dB)$$

The signal to noise ratio at the home receiver is the sum of the distribution system's noise figure and the input signal to noise ratio as given

$$(Signal/Noise\ ratio)_{home\ receiver}\ (dB) = (Signal/Noise\ ratio)_{input}\ (dB) + NF_{distribution\ system}\ (dB) \qquad (20)$$

where the noise figure is given in ratio form as

$$NF_{distributionsystem} = NF_i + \frac{(NF_{i+1}-1)}{G_i} + \frac{(NF_{i+2}-1)}{G_i G_{i+1}} \ldots \frac{(NF_n-1)}{G_i G_{i+1} \ldots G_{n-1}}$$

The components which make up the distribution system are comprised of a variety of amplifiers, splitters, combiners and transmission lines. Fig. 21 suggests a potential configuration of the receiving system. The components used are representative of what is available in the market.

The main component in the distribution system for both the satellite and terrestrial portions of the system is the amplifier following the antennas. This component contributes the most to the noise figure. A survey of available components shows a typical specification for the satellite LNB to have a noise figure ranging from 2 to 3 dB and a gain of 55 ± 3 dB. In the case of the terrestrial portion, the amplifier has a noise figure of 5 dB and a gain of 20 dB. The remainder of the system includes the splitters, amplifiers and transmission lines. The splitters divide the signal to each of the individual homeowners. The splitters induce a loss as well as add to the noise figure of the system. The transmission line for this example is coax cable(RG-59) which has a bandwidth up to 1450 MHz and an attenuation factor of 0.07 dB/ft at a frequency of 1450 MHz and attenuation factor of 0.023 dB/ft at a frequency of 100 MHz. The transmission line, attenuation is due to loss and adds an equal factor to the noise figure. Table 20 summarizes the loss in dB for each of the corresponding transmission line lengths involved in the problem. The gain and noise figure of all the components are used to calculate an overall distribution system gain and noise figure.

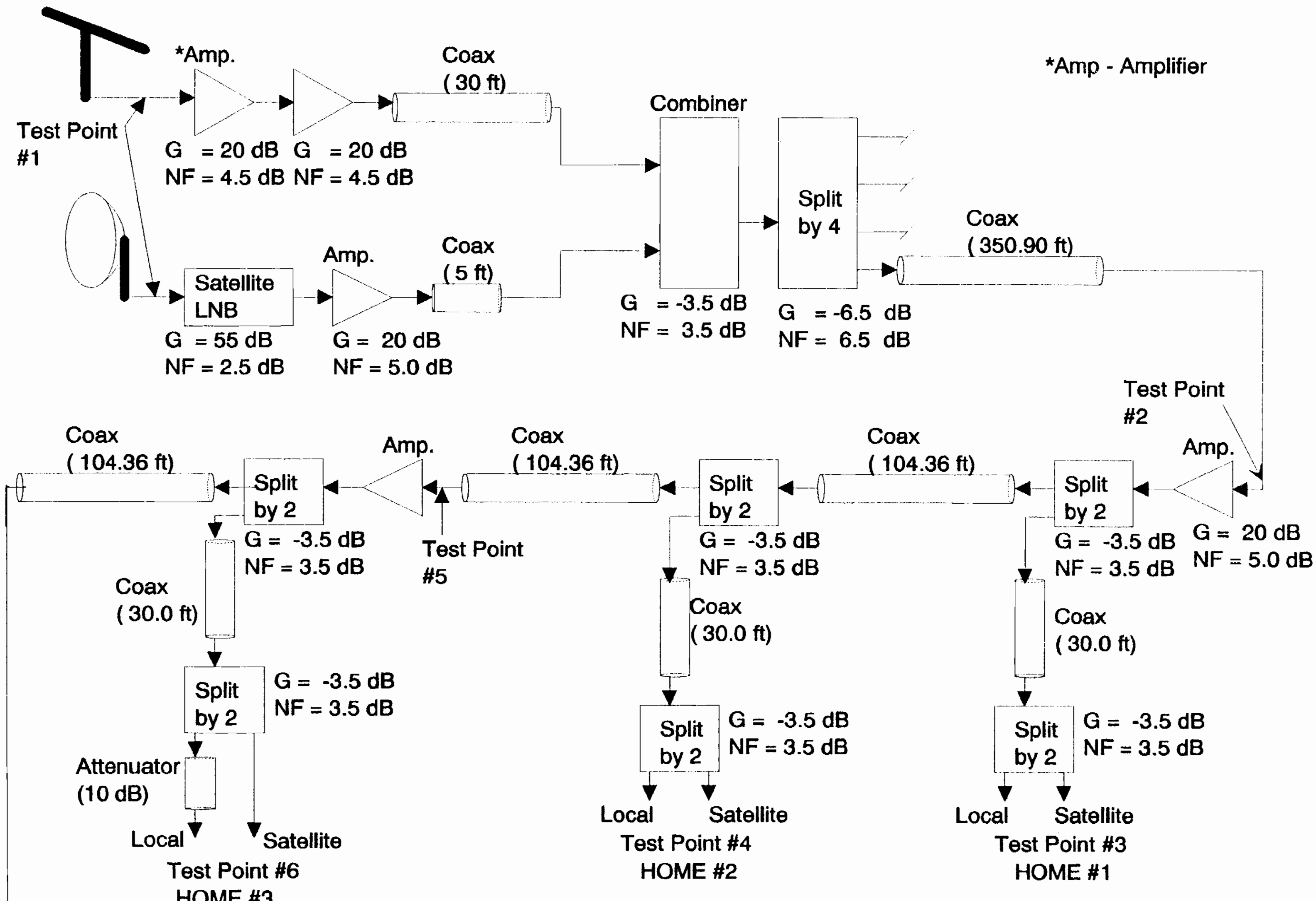

Figure 21. Suggested SACT detailed system configuration

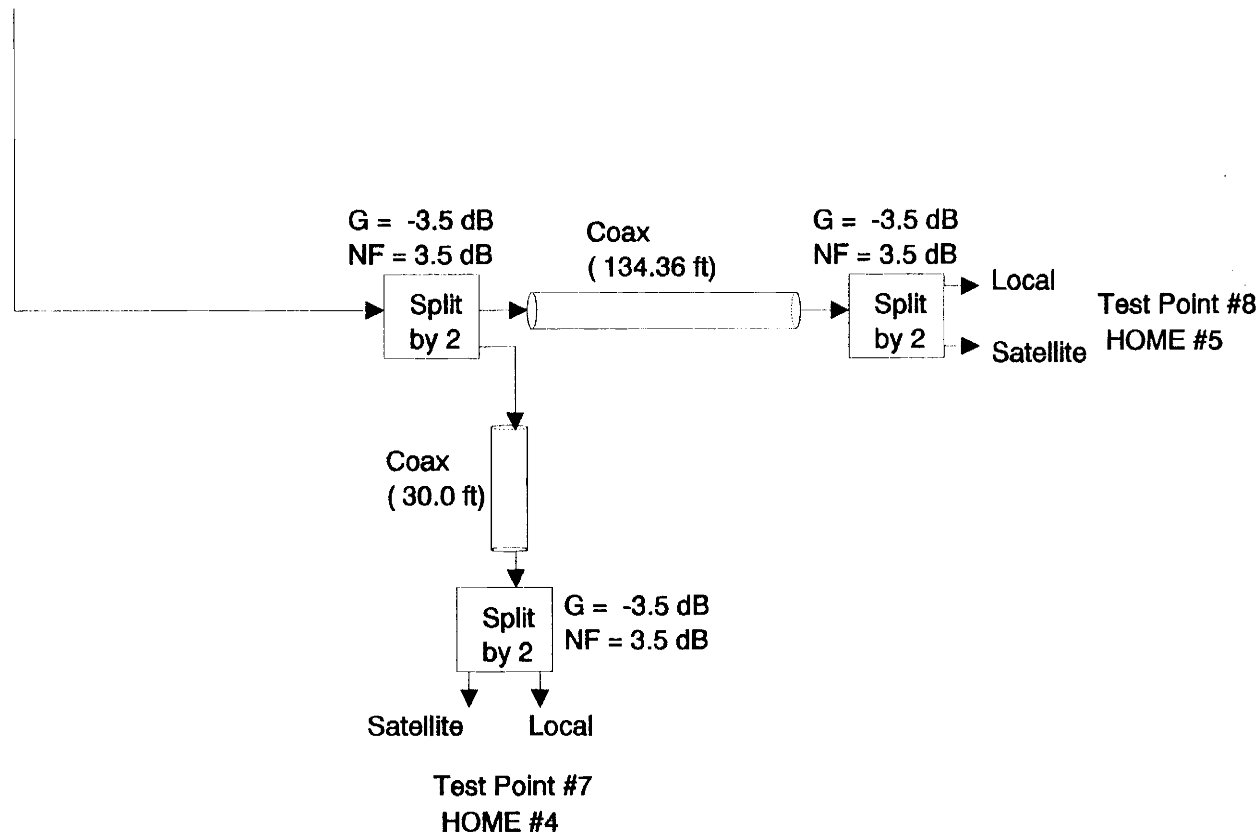

Figure 21 (continued). Suggested SACT detailed system configuration

Limits on the gain and noise figure of the distribution system are equal to the following according to the difference between the input signal levels and the receiver signal levels which are specified in Section 2.12.

For the Satellite System:

$$Gain_{min}(dB) = P_{home\ receiver}(dBm) - P_r(dBm)$$
$$= -65\ dBm - (-84.23\ dBm)$$
$$= 19.23\ dB$$

$$Noise\ Figure_{max}(dB) = -(S/N\ ratio)_{home\_receiver}\ (dB) + (S/N\ ratio)_{input}\ (dB)$$
$$= -11.0\ dB + 15.29\ dB$$
$$= 4.29\ dB$$

For the Terrestrial System:

$$Gain_{min}(dB) = P_{home\ receiver}(dBm) - P_r(dBm)$$
$$= -57.49\ dBm - (-69.49\ dBm)$$
$$= 12\ dB$$

$$Noise\ Figure_{max}(dB) = -(S/N\ ratio)_{home\_receiver}\ (dB) + (S/N\ ratio)_{input}\ (dB)$$
$$= -20\ dB + 36.55\ dB$$
$$= 16.55\ dB$$

Table 20. Transmission line losses for the corresponding lengths

Transmission Line Lengths (feet)	Terrestrial signal (dB)	Satellite signal (dB)
5	----	-0.35
30	-0.69	-2.1
104.36	-2.40	-7.30
134.36	-3.09	-9.40
350.90	-8.07	-24.56

The worst case gain and noise figure of the distribution system is equal to 31.29 dB and 2.504 dB respectively for the satellite system at test point 8 and 27.65 dB and 4.57 dB respectively for the terrestrial system at test point 3. The system gain and noise figure in this case are both acceptable. The important conclusion is that the distribution system does not have a major affect on the gain or noise figure of the system. Furthermore, Table 21 shows that the signal level requirements are being met for each home in the chain. The test points show the outcome for one branch of the divided system. All other branches should be identical to the one shown.

5.3 INTERFERENCE

The main interference problem is caused by attempting to combine the terrestrial signal with the satellite signal for distribution over the same path. The terrestrial signal is a group of channels, amplitude modulated in the bands from 54 Mhz to 80 MHz and from 470 MHz to 900 MHz. The satellite LNB signal is a group a channels, frequency modulated, in the band from 950 to 1450 MHz. Because they are in different frequency bands there is no expectation of interference. Possible problems may be produced by spurious signals generated from amplifying either the terrestrial antenna or satellite LNB. This problem is avoided by not saturating any of the pre-amps or in-line amplifiers. The test to ensure that this does not occur is that the input signal to any of the amplifiers cannot be greater then the amplifier's third order intercept point minus the amplifier gain. This condition requires the input signal to any of the amplifiers shall not exceed -5 dBm. This condition is met for he test points in the system.

Table 21. Test points set-up throughout system. Fig. 20 illustrates the test points location

Test Point	Signal Power (dBm)				
	Channel 7	Channel 10	Channel 13	Channel 21	Satellite
1	-58.31	-59.14	-40.90	-69.49	-84.23
2	-37.07	-37.90	-19.66	-48.25	-44.14
3	-24.76	-25.59	-7.35	-35.94	-33.24
4	-30.66	.31.49	-13.25	-41.85	-44.04
5	-28.87	-29.70	-11.46	.40.05	-45.74
6	-16.59	-17.39	-9.91	-27.74	-34.84
7	-22.46	-23.29	-5.05	-33.64	-45.64
8	-24.86	-25.69	-7.45	-36.04	-52.74

6.0 CONCLUSION

This report analyzed and developed an upgrade to a sample community television reception considering three alternative systems. The alternative systems include cable, individual terrestrial and satellite systems and variety of community oriented systems. For each case under the three alternatives a life cycle cost and system analysis was completed. From the life cycle cost and system analysis, an alternative was chosen to be further analyzed and proposed to the community where each step followed the systems engineering process which considers all aspects of a system..

The system proposed to the community is the least cost option presented . It is referred to in this report as Shared Antenna Community Television (SACT). The basic concept behind this alternative is that the community would receive terrestrial and satellite television within a common area and distribute it throughout the community. This option has advantages beyond cost. The implementation of this option gives the homeowner flexibility in choosing the extend of their investment into a system. A homeowner could, with this option, have the choice to upgrade only their local or satellite television, with the local television upgrade being significantly less expensive then if the homeowner choose an individual system. In addition this option is atheistically pleasing for the community because under this alternative the community would not be cluttered with individual satellite and terrestrial antenna systems.

Furthermore the SACT system met the remaining operational requirements as stated Section 2.1. The MTBF of the system was calculated to be 11,171.8 hours which was well above the system requirement of 7992.0 hours to ensure an system availability of 99.9 %. Also, the television signal had to meet specifications for a signal level, signal to noise ratio and signal reliability. The signal level for the terrestrial portion of the system was specified between -51.0 dBm and -5 dBm, with a signal to noise ratio of greater then 20 dB. In all case as shown in Table 21 the output signal fell within the specified range. In addition the worst output signal to noise ratio was equal to 31.98 dB which is well above the 20 dB specification. In the case of the satellite system its signal range was specified from -65 dBm to -25 dBm. Again, as shown in Table 21 the output signal fell within these specified ranges. In addition the worst case output signal to noise ratio was equal to 12.78 dB which is above the 11 dB specification.

APPENDICES

APPENDIX A: Satellite Programming

This appendix includes a portion listing of what programming is available on three different services including for C-band satellite programming, DirecTV and USSB. Table A-1 includes a portion listing of what popular programming is available in C-band. This is a partial listing from a group of 20 accessible satellites(Satellite Orbit, 1995, p.65)

Table A-1 Partial listing of available programming in C-band from locally accessible satellite systems

Channel	Galaxy 5	Satcom C3	Galaxy 1R	Satcom C4	Satcom C1
1	Disney	Family Channel	Comedy Central	AMC	Sports Channel
2	Playboy	TLC	Galavision	Request TV 2	KUSA (ABC)
3	TBN	Viewers Choice	Encore	Nickelodeon	KRMA (PBS)
4	Sci-Fi chanel	Lifetime	TV food Net	Lifetime-east	Sports Channel
5	CNN	Faith and Values Network	Classic Art Showcase	Deutsche Welle	KDVR (FOX)
6	TBS	Court TV	Z Music	MSGN	KMGH (CBS)
7	WGN Chicago	C -Span	Disney Channel	Bravo	Prime Sports
8	HBO-west	Q2 shopping	Cartoon Network	Superstar Preview Guide	NBC-east
9	ESPN	Music choice	ESPN	QVC	Sports Channel

Table A-1 (continued). Partail listing of available programming in C-band from locally accessable satellite systems

10	MOR music TV	Home Shopping Network	America's Talking	Home Shopping Network	Prime Sports
11	Family Channel east	Prime Network	EWTN	The Box	Network one
12	Family Channel west	History Channel	Value Vision	NuStar Promos	Sports Channel
13	CNBC	Weather Channel	Encore	Travel Channel	Sports Channel
14	ESPN2	NESN	ESPN	Cable Health Club	KCNC (NBC)
15	HBO-east	Showtime-east	CNN	WWOR New York	Sports Channel
16	Cinemax west	MTV-west	Turner Classic Movies	Request TV	NewSport-west
17	TNT	TMC	New Inspiration Net	MTV-east	Cal channel
18	TNN	Nickelodeion	HBO	Viewers Choice	Prime SPorts
19	USA network	Showtime compressed video	Cinemax	C-SPAN2	FoxNet
20	BET	Jones compressed video	HGTV	Showtime-west	International Channel
21	MEU	Comedy Central	USA Network	Discovery-east	Prime Sports
22	CNN headline news	Sports showcase	Cinemax	TMC	Prime Sports
23	A$E	Entertainment TV	TBA	VH-1	KWGN

DirecTV Programming

News: CNN, CNN international, C-Span, C-Span2, Headline News, The weather channel, Bloomberg Information TV, Newsworld international

Educational: The Discovery Channel, learning Channel

Sports: ESPN, ESPN2, Local regional sports

Music: Country Music Television, Much Music, Music choice, The Nashville network

Movies: American Movie Classics, DirecTV pay per view, ENCORE(60's, 70's, 80's), ENCORE(Love stories), ENCORE(Westerns), ENCORE(Mystery), ENCORE(Action), ENCORE(True stories and drama), ENCORE(WAM!), ENCORE(sampler)

Other: Americas Talking, DirecTV preview channels, The Disney Channel(east and west), Entertainment Television, The Family channel, The Travel Channel, Superstation TBS, TNT, TRIO, Turner Classic Movies, USA Network, A$E, Cartoon Network, CNBC, Court TV, Sci-Fi channel

USSB Programming

Pay Channels: Cinemax, Cinemax 2, Cinemax west, HBO, HBO2, HBO3, HBO west, HBO 2 west, Showtime, Showtime 2, Showtime west,

Music: MTV, VH-1

Other: All new channel, Comedy Central, Lifetime, Nickelodeon, Nick at Nite, The movie channel, The movie channel west, USSB background, FLIX

APPENDIX B : Terrestrial and Satellite Transmit Power Levels

This section includes a listing of EIRPs or transmit power levels for a portion of the terrestrial broadcast stations and of the satellite systems accessible in the area of the Twin Meadows housing development.

Table B-1 Terrestrial broadcast station statistics

Terrestrial Broadcast Station	Freq. (MHz)	Band (Mhz)	Trans. Height Above Terrain (ft)	Trans. Location (Mount.)	Trans. EIRP (dBW)
7(CBS)	174-180	6	2000	Poor	56.0
10(NBC)	192-198	6	2000	Poor	56.0
13(ABC)	210-216	6	1960	Thaxton	56.0
21(FOX)	512-518	6	1640	Flat Top	64.0
27(FOX)	548-554	6	2049	Poor	64.0

Table B-2. Satellite system statistics

Satellite	Freq.	Bandwidth (Mhz)	EIRP(dBW)	
			Horizontal (Pol)	Vertical (Pol)
Analog C band				
Galaxy I	C	36	39.6	39.1
Galaxy V	C	36	39.5	39.5
SATCOM C1	C		37	37
SATCOM C2	C		40	40
SATCOM C3	C		40	40
Digital Ku-Band				
DBS-1	Ku	27	60.0	60.0
DBS-2	Ku	27	60.0	60.0
DBS-3	Ku	27	60.0	60.0

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