A COMPUTER DESIGN OF CATV DISTRIBUTION SYSTEMS

Ivan T. Frisch, Vice President
Bill Rothfarb, Sr. Engineer
Aaron Kershenbaum, Sr. Engineer

Network Analysis Corporation
Beechwood, Old Tappan Road
Glen Cove, New York 11542

Abstract

CATV distribution systems are expensive. To reduce hardware costs, we have developed a package of computer programs that generates complete layouts and designs for CATV distribution systems. Since the computer does not rely on "intuition", it is not restricted to using routine approaches but is free to select the best combination of components and layout which meet the system specifications.

To illustrate how money can be saved with network optimization by computer, we examine a number of results derived from actual computer runs. These results include the layout of feeder and trunk cable, the location of distribution amplifiers, and detailed assignment of amplifier locations as a function of cable sizing and coupler assignments. The computer's designs not only save money but are free of the approximations, rules of thumb and inadvertent errors introduced by human designers.

Introduction

The large number of subscribers and the requirements on signal quality make well-designed broadband cable television systems among the most difficult networks to achieve. For this reason we at Network Analysis Corporation have combined modern network analysis and computer methods to optimize CATV distribution system design. The result is a computer program which completely engineers a CATV distribution system. The computer-designed systems, when compared to manually-designed systems are produced faster, are more dependable and have significantly lower hardware cost. Furthermore, once a design has been developed, its details and specifications are already in a form suitable for computerized inventory, maintenance and replacement studies.

The Problem

The CATV system designer is faced with a host of competing variables and requirements such as cross-modulation, noise, bandwidth, temperature, alternate routes and component characteristics. Somehow, he must contend with all of these factors to produce his design. The design involves many crucial decisions.

TABLE 1

The Complex Decisions for CATV Design

- Selection of head end sites
- Location of messenger cable
- Selection of trunk distribution points
- Selection of components and manufacturers
- Selection of amplifier output levels and gains
- Location of trunk and feeder cable
- Sizing of cable, location of amplifiers and assignment of splitters and couplers
- Specification of tilt compensation, padding and settings for amplifiers
- Assignment of automatic gain and slope control, and temperature compensation
- Specification of subscriber taps
- Location of power supplies
- Provision for future system expansion

If any of these aspects are not given adequate consideration, the result can be a costly or a low performance design.

The result of the design process must be a complete design detailing: location and specification of all components including cable, couplers and amplifiers, signal levels, cross modulation and noise levels throughout the system, a bill of materials, and all of the other items shown in Table 1 above.

To cope with all this, the human designer must compromise and decide on many of the design parameters either independently or without examining the full range of interactions among them. These compromises can be costly. In all cases in which good manual designs produced by professional designers have been directly compared with designs independently generated by NAC's computer programs, the computer has produced substantial savings while obtaining equal or superior system performance. The savings on hardware have ranged from 8% to 40% of the cost of the manual design. Even for a small system with only 15 miles of strand, NAC's design was 8% lower than the best effort of a group of designers who designed their system as part of a competition among themselves.

Examples of Savings by Computer CATV Design

Since the computer does not rely on "intuition", it is not restricted to using routine approaches that were developed to handle similar but not identical cases. The computer is free to select the best combination of layout and components which will meet the system specifications. After studying the results of the computer's optimizations, it becomes evident that the computer designs are based on sound engineering principles applied in unique and original ways to each particular situation. The best way to illustrate how money can be saved using NAC's computer CATV design program is to examine results derived from actual computer runs. Component specifications for these examples are shown in Table 2.

The computer can, of course, use any components with any characteristics from any manufacturer or manufacturers. The simplified characteristics in Table 2 are representative and are used for the sake of illustration. The specifications, such as output level, which is normally chosen by the computer, are assumed to have been selected on the basis of overall system constraints on noise, cross modulation, intermodulation and performance under temperature variation. Thus, the examples are reduced to their simplest terms.

In the examples we assume the following system specifications and constraints:

1. The telephone poles are located 100 feet apart.
2. The minimum signal level at the termination of any feeder is 26 dBmV for an undedicated system. Amplifier gains have been derated to allow for subscriber tap losses.
3. There can be no more than two extender amplifiers in any cascade.

4. Cable size can change only at a splitter, coupler, or amplifier.
5. Amplifier output levels must be exactly as in Table 2. Variable gains and equalizers are included in the amplifiers.

6. Items such as AGC, power supplies and reflections are ignored for case of illustration.

● A cable television distribution system involves a vast number of possible structures or layouts--far too many to select by eye, experience, intuition, or by evaluating every possibility. For example, examine the strand map shown in Figure 1. Any CATV designer would consider this system trivial--there are only 4 blocks with 4 telephone poles per street. Yet for even this simple example, if every street is to be covered, there are 49,152 possible feeder cable layouts. One possible layout is shown by the heavy lines.

It is easy to see that even for a very small town with only 15 miles of strand, the number of possible layouts is so large that both intuition and brute force enumeration of all possibilities fail as optimum design methods. In fact, for most small systems if one were to cover the earth with computers each 1 square inch in area and each making one million evaluations per second, it would take more than the lifetime of the universe to examine all possible system layouts for the town. NAC's computer programs are able to avoid these problems to produce savings.

● Cable is available in certain fixed diameters. For trunks, designers usually select .412 inch, .500 inch, .750 inch or 1.00 inch coaxial cable. The discreteness of cable sizes can invalidate most insights the human may have while at the same time creating a huge and onerous selection from possible cable size combinations. Even for the small section of trunk shown in Figure 2, with cable sizes changing only at splitters or amplifiers, and allowing only two possible sizes for the trunk, there are 1024 possible cable size combinations.

Figure 3 shows how the computer's optimum choice of cable has reduced the hardware cost in one actual case of trunk design. We assume the location of the first trunk amplifier is given. The next trunk amplifier is moved 1.5 db left, a splitter combination is changed and as a result $78.00 is saved in cable cost.

- The steps required in creating a well designed CATV system are all extremely dependent on one another. It is usually impossible for a human designer to consider simultaneously even a small number of interacting problems, i.e., distribution point locations and the complete feeder and trunk layout. But to find the lowest cost system, many factors must be considered simultaneously. The human uses rules of thumb to reduce his problem to a manageable size. For example, one such rule used by some designers is: "keep the trunk as short as possible by pulling back the distribution points as far as possible." A design using this philosophy is shown in Figure 4a. The feeder design shown is the best possible one given the distribution point. A superior design, produced by the computer, is shown in Figure 4b. This design has a longer trunk and even has an extra trunk amplifier. But it costs $158 less.

- Changes in one part of a design can often have suprisingly significant effects on other seemingly remote parts of the system. Engineers have great difficulty in considering more than one local area at a time. For example, in the system of Figure 5a, a designer placed a 3-way hybrid splitter, the SP3W, on one output of the trunk bridger. He correctly judged the trunk bridger with 4 feeder outputs to be wasteful in this situation. Looking at the overall picture, the computer cascaded an SP8 and an SP3 to obtain the design shown in Figure 5b., using one less extender amplifier, with a resultant saving of $92.

- Small changes in design decisions can cause large changes in cost and performance. One of the most complex decisions is the location of distribution points. $140 was saved by moving the distribution point only 100 feet from the position in Figure 6a to the position in Figure 6b even though the layout was not affected. The money was saved by removing extender amplifiers and converting .500 cable to .412 cable.

In some cases it is undesirable to use more than one cable size for feeder cable. This may be due to the added cost of inventory or the added installation problems. However, often costs can be assigned to these factors. When they are added into the cost of cable, it is usually still worth while to use more than one cable size. Certainly, in many cases near the ends of feeder lines, small sections of cable of large diameter can eliminate many extender amplifiers. The computer can take these factors into account in its optimization.

- For the sake of simplicity, the above examples have been for undedicated systems. NAC's computer program integrates the assignment of subscriber taps into the overall design procedure to achieve large additional savings over conventional techniques. For example, the system in Figure 7. is a good manual design for a system designed with a flat loss allowance for subscriber taps of 6 dB between extender amplifiers. Required subscriber tap locations are indicated by darkened squares.

When the taps are added to this system, the resulting design will have four extender amplifiers. However, if the design procedure takes into account the actual tap losses rather than allowing a fixed flat loss, savings can be made. Thus, for the taps with characteristics shown in Figure 8 with a required signal of 11 dBmV at the tap output at 270 mHz , the design in Figure 9 is achieved with the given tap locations. The extender amplifier inputs can now go as low as 20 dBmV and the extender gains are 17 dB or 20 dB. Note that only two extender amplifiers are now required instead of four.

A Complete CATV Computer Service

As mentioned previously, the above examples were simplified for case of illustration. The computer program also performs temperature and AGC calculations, assigns equalizers, locates power supplies, and can add extra poles and strand where allowed and where economical.

In addition to the savings, speed and performance assured in performing these operations by computer, there are two other striking advantages.

a. Suppose a new line of components appears on the market. The human designer must begin anew to gain experience before he can produce efficient designs. NAC's program has no such problem. The computer has actually designed systems with components that do not yet exist but are being considered as possible new products. The computer program is simply fed the characteristics that the manufacturer would like his device to have and the computer program produces its design. The manufacturer can then judge whether the proposed device is worth producing. Among the system features the program has evaluated are integrated circuit components, two-way systems, new lines of equipment and specialty items.

b. Once a system has been built, the program is not through. It can be used to set up a data base for inventory maintenance and replacement schedules, and to monitor, study, adjust, alter or update the system throughout its lifetime. Its uses have included:

- Aging and replacement studies
- Modernization by using new equipment
- System expansion
- Expansion of capabilities
  - bandwidth
  - addition of two-way sections

Conclusion

The CATV industry stands at the threshhold of one of its most explosive and vital periods of growth. The design decisions and commitments made now will have long lasting effects on the cost, performance and ultimate capability of the vast cable television enterprise. It is essential that these new systems be designed efficiently and economically. NAC's computer CATV design program can play a vital role in this effort.

COMPONENT CHARACTERISTICS

COMPONENT	TRUNK OUTPUT LEVEL (DBMV)	MAXIMUM GAIN ON TRUNK (DB)	FEEDER OUTPUT (after all splits) (DBMV)	MAXIMUM GAIN TRUNK TO FEEDER (DB)
TRUNK AMPLIFIER	29	22.5	—	—
	SYMBOL:			
	COST:	$350		
TWO OR FOUR FEEDER TRUNK BRIDGER AMPLIFIER	29	22.5	42	48
	TWO FEEDER SYMBOL:		FOUR FEEDER SYMBOL:	
	COST:	$600	COST:	$700
TWO OR FOUR FEEDER DISTRIBUTION AMPLIFIER	—	—	42	36
	TWO FEEDER SYMBOL:		FOUR FEEDER SYMBOL:	
	COST:	$400	COST:	$500

COMPONENT	FEEDER OUTPUT LEVEL (DBMV)	MAXIMUM GAIN ON FEEDER (DB)
EXTENDER AMPLIFIER (one in cascade)	40	14
	SYMBOL:	
	COST:	$150
EXTENDER AMPLIFIER (two in cascade, must be used for both amplifiers in a cascade of two)	37	11
	SYMBOL:	
	COST:	$150

CABLE

.500": 1.5 db loss/100' at 270 MHZ
SYMBOL: ---- COST: $.095/ft.

.412": 2.0 db loss/100' at 270 MHZ
SYMBOL: —— COST: $.065/ft.

SPLITTERS AND COUPLERS

$16: SP8 — 1.5 db loss; 8 db loss

$18: SP3 — 3.5 db loss; 3.5 db loss

$19: SP3W — 6.5 db loss; 3.5 db loss; 6.5 db loss

Table 2
Extender amplifier gains have already been reduced by 6 dB to allow for tap insertion losses in examples of designs of undedicated systems.

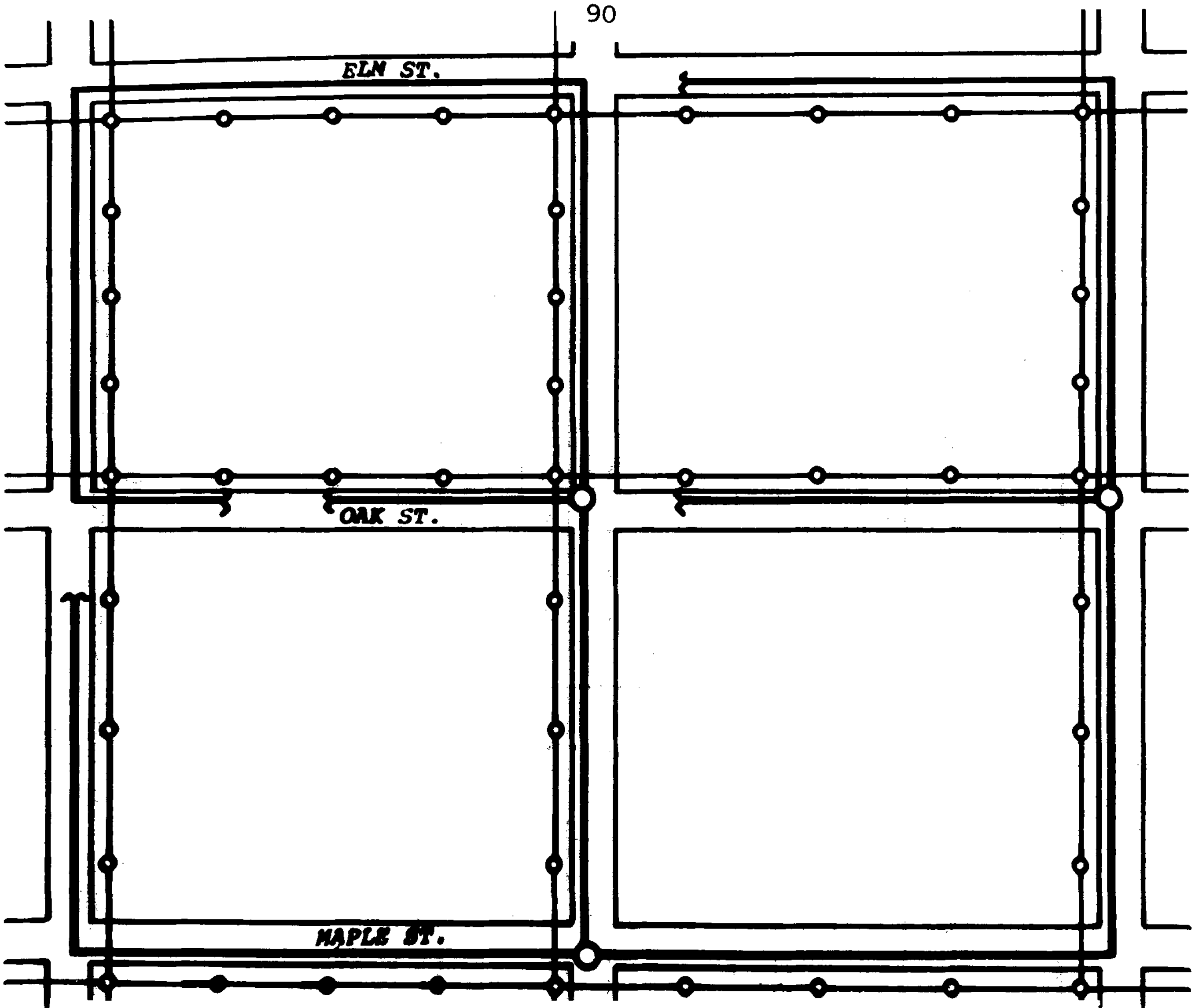


Figure 1
There are 49,152 possible feeder layouts for this four block strand map.

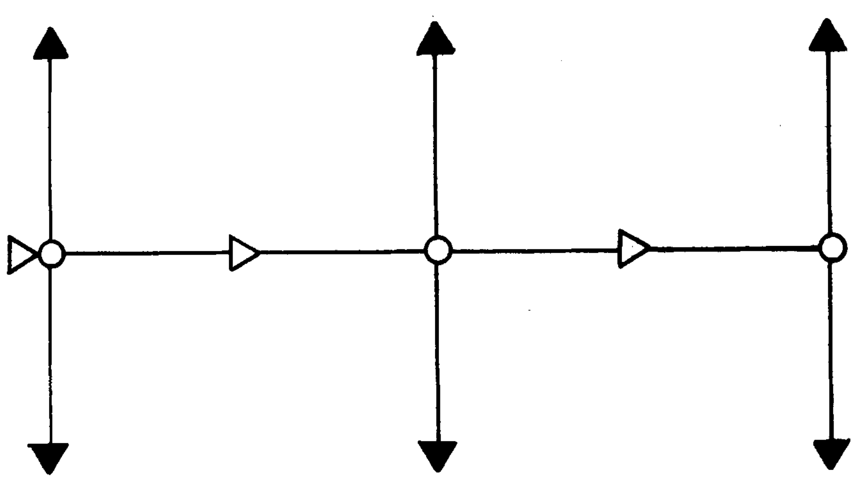


Figure 2
There are 1,024 possible cable diameter combinations for this layout.

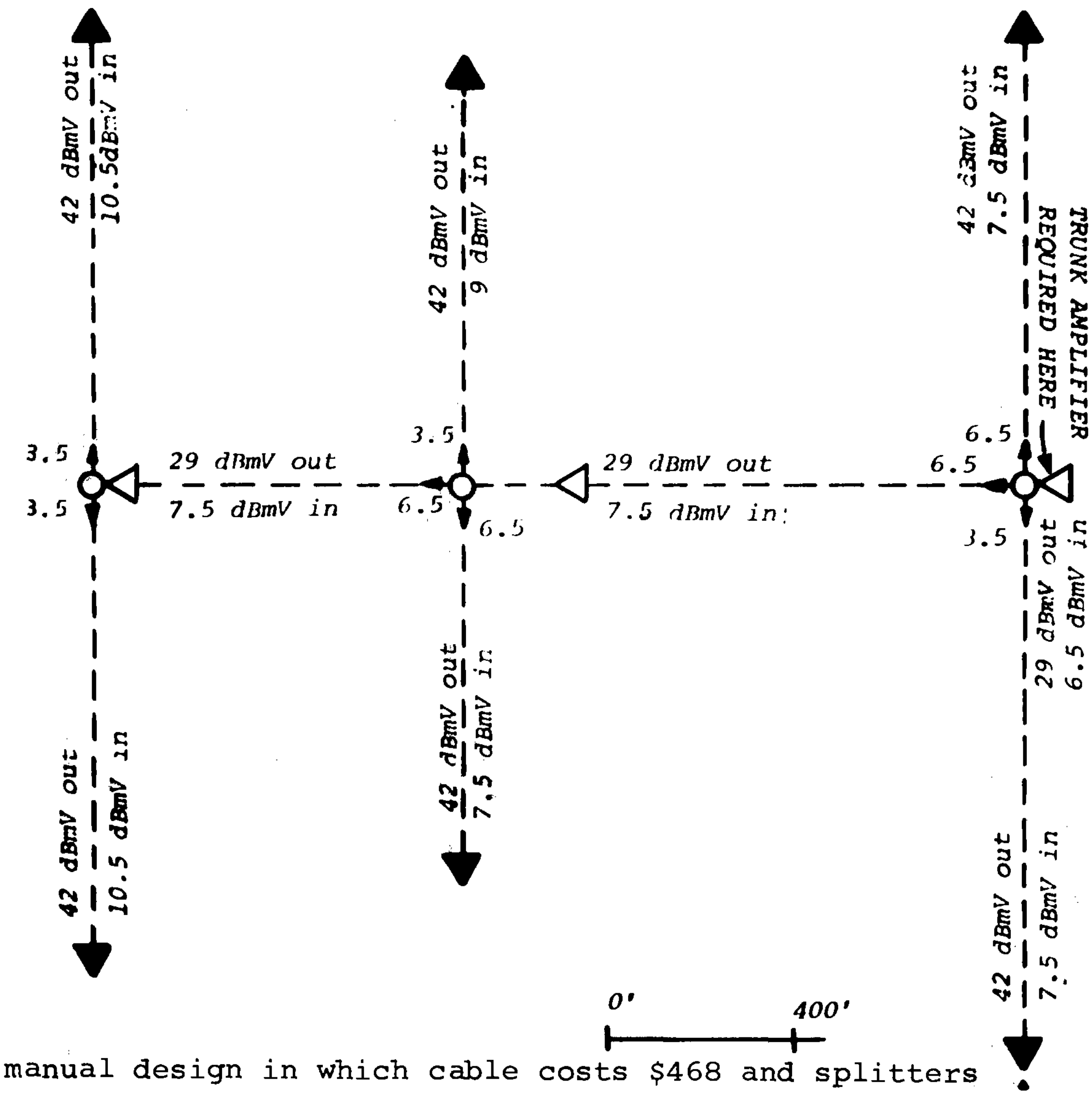


Figure 3a
An excellent manual design in which cable costs $468 and splitters cost $56.

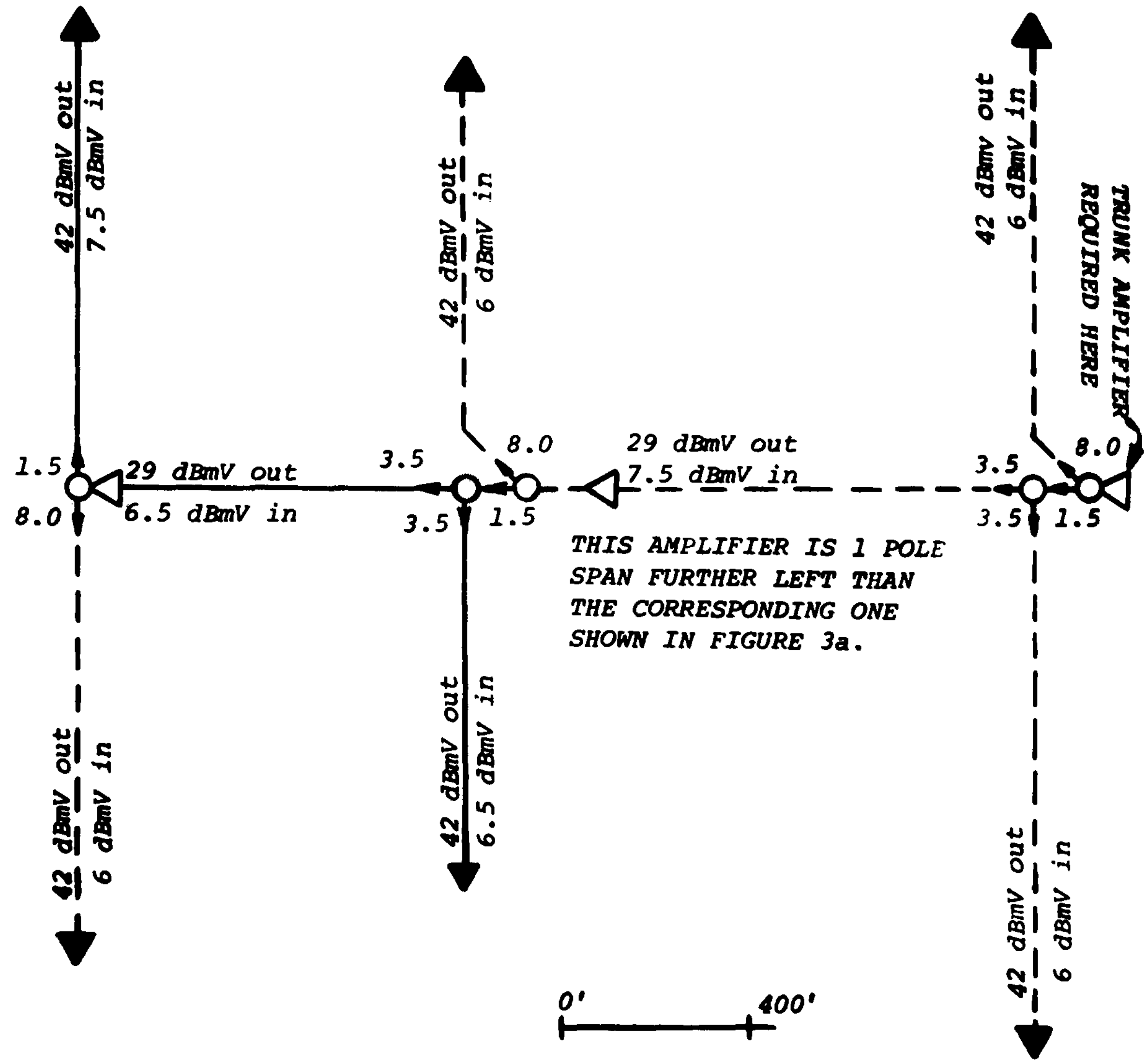


Figure 3b
In NAC's computer design splitters cost $84 but the cable cost saving is $78.

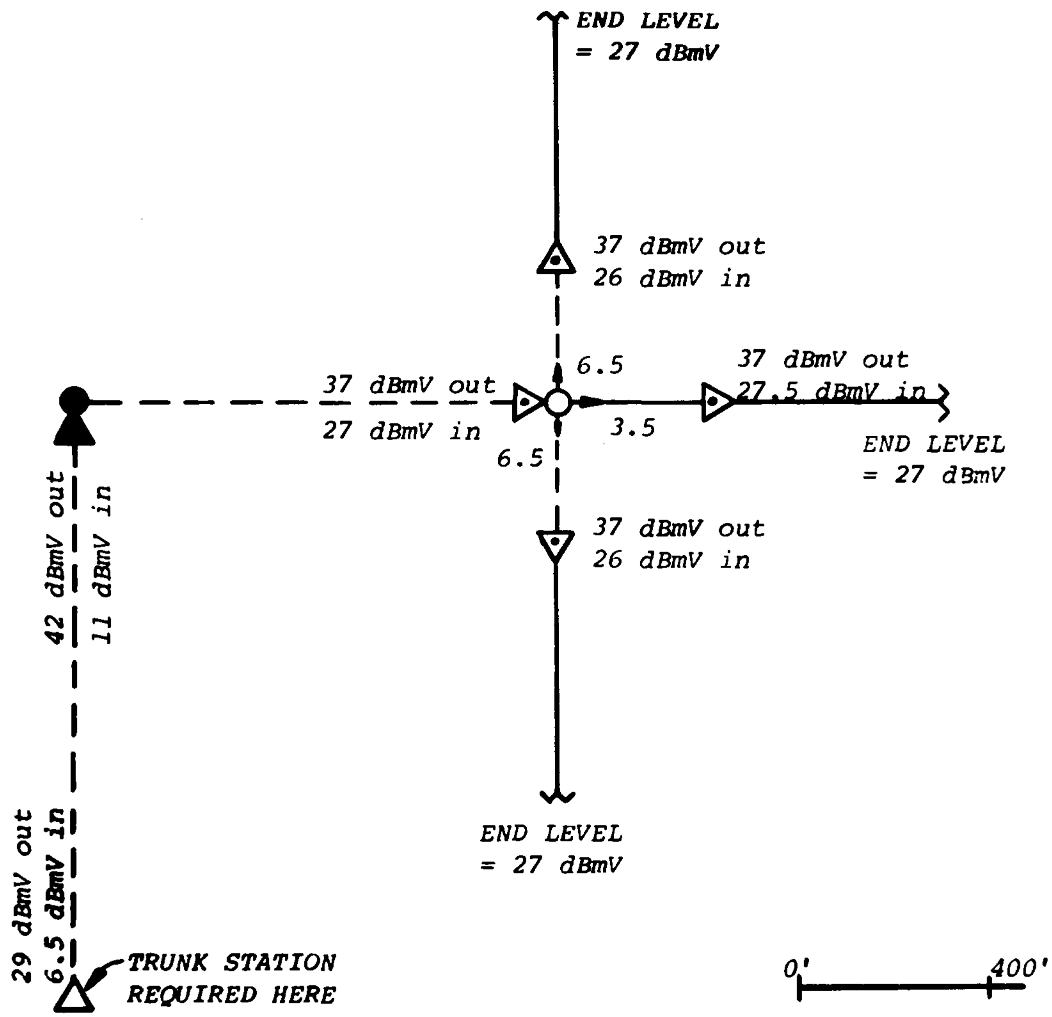


Figure 4a
Manual design.

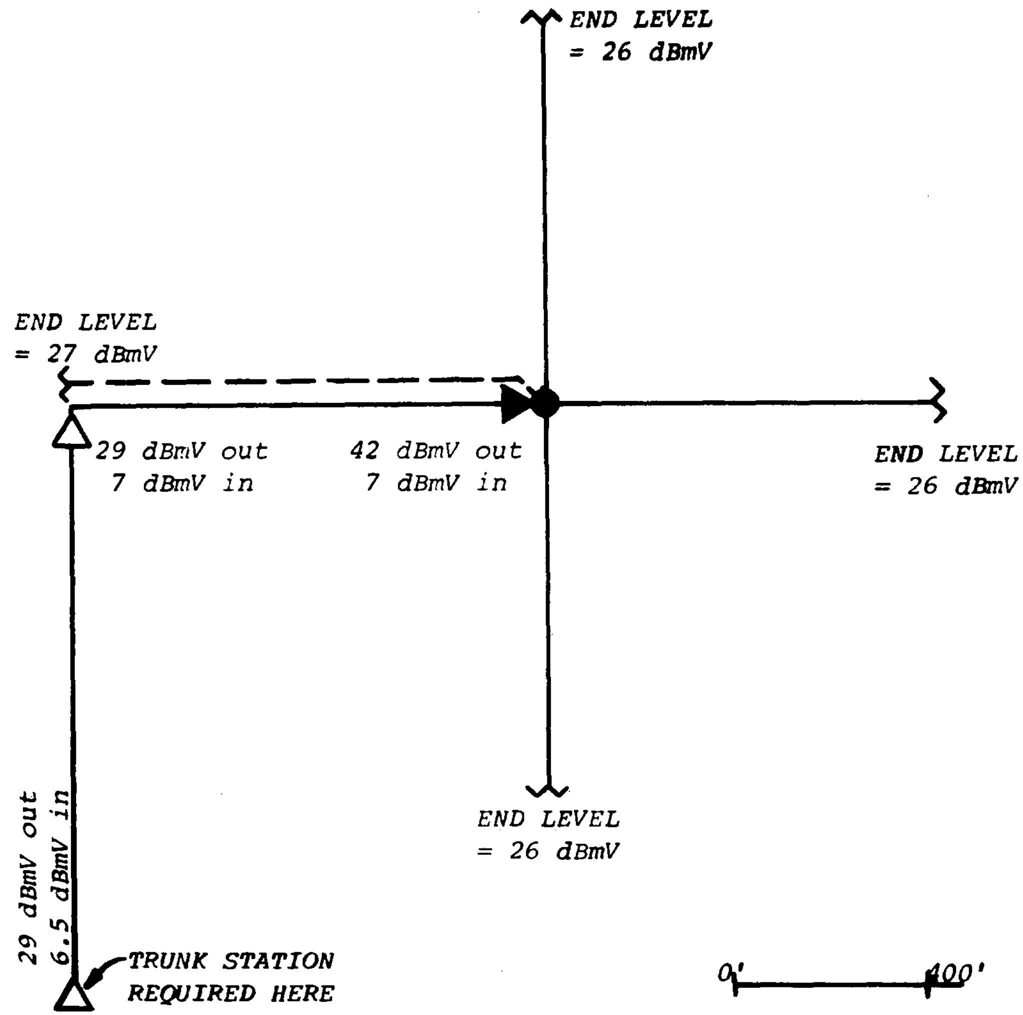


Figure 4b
The computer design costs $158 less--even though the computer design (Fig. 4b) contains one more trunk amplifier and has more trunk cable than the man-made design (Fig 4a).

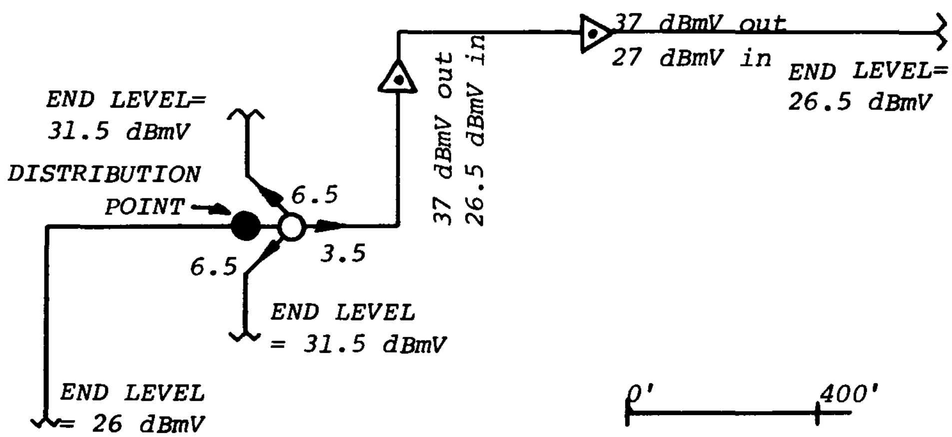


Figure 5a
Manual design.

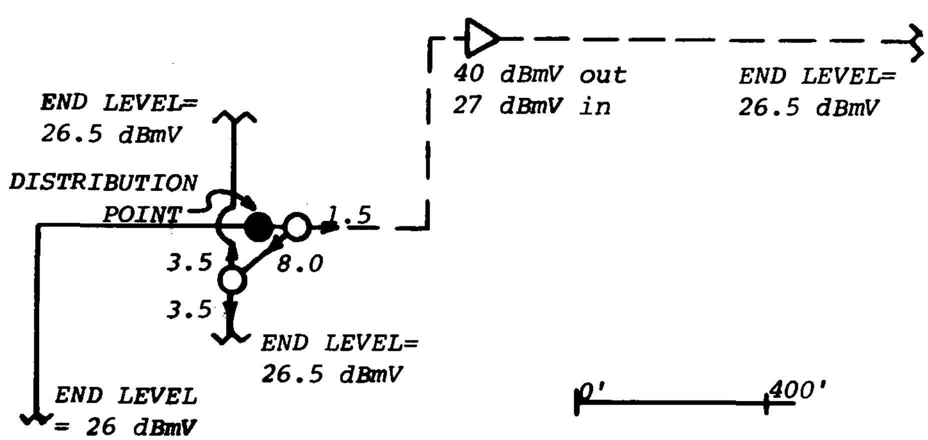
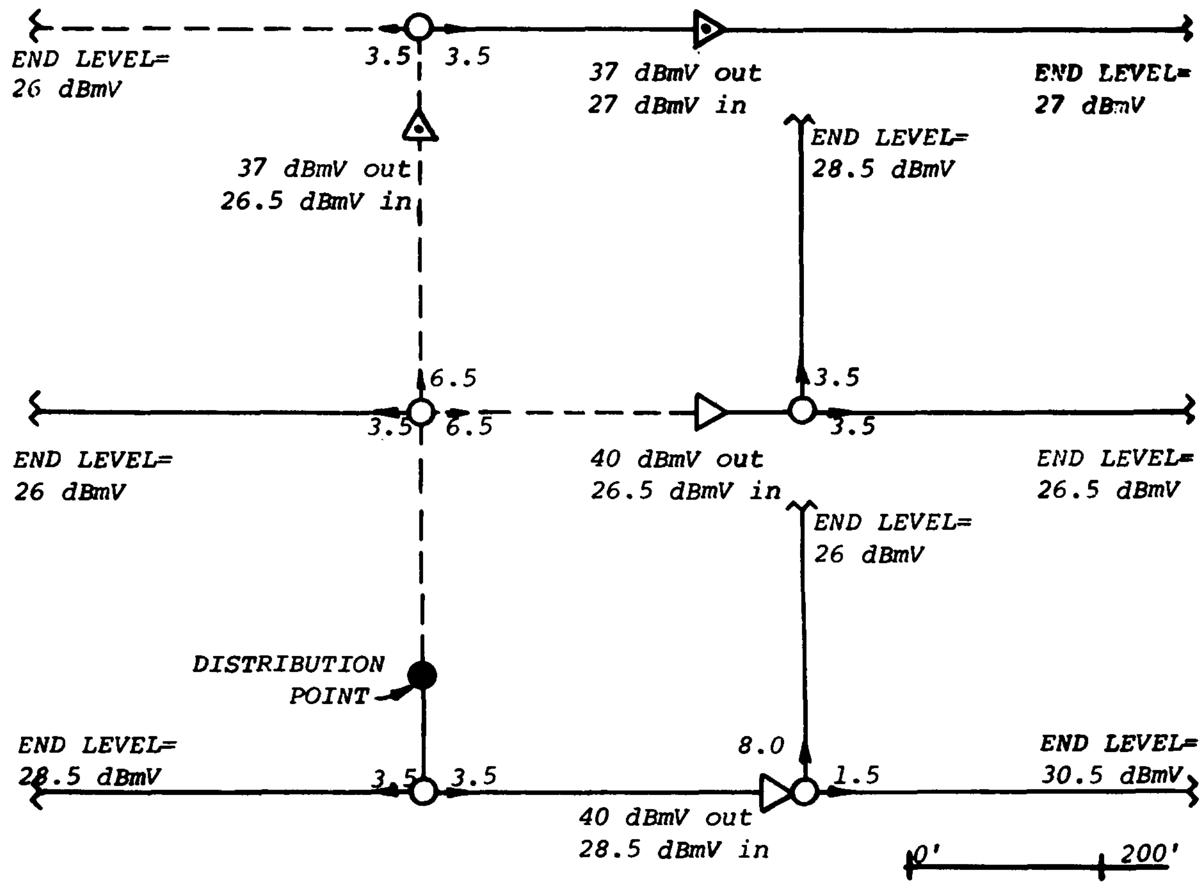


Figure 5b
NAC computer design. The computer excels at solving a tough problem--tailoring splitter losses to system needs. The computer design (Fig. 5b) saved more than 17% of the cost of the human designed system (Fig. 5a). It did this by using a directional coupler instead of a hybrid splitter at the distribution amplifier and by making better use of amplifiers and cable.



<u>Figure 6a</u>
Manual design.

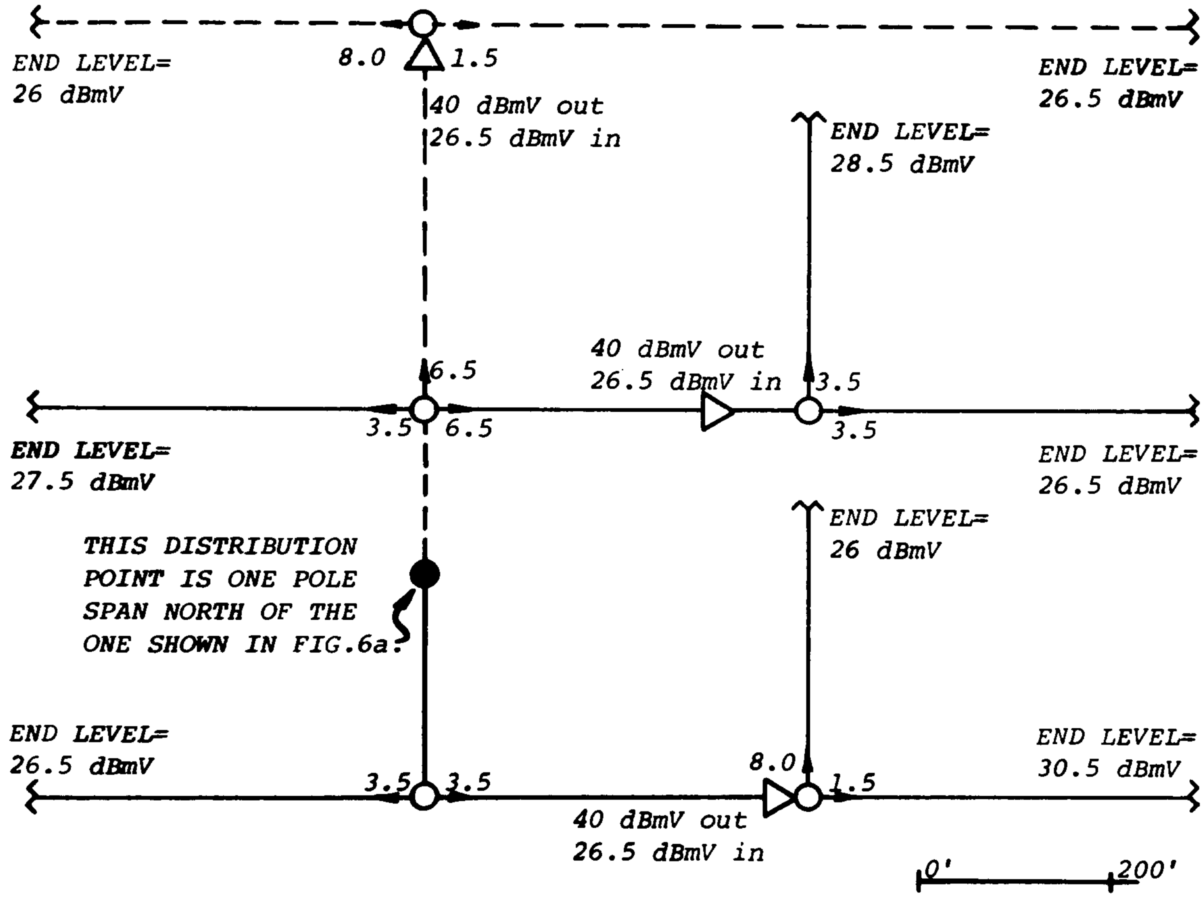


Figure 6b
In NAC's computer design, a 100 foot difference in distribution point location saves $140 or 13%.

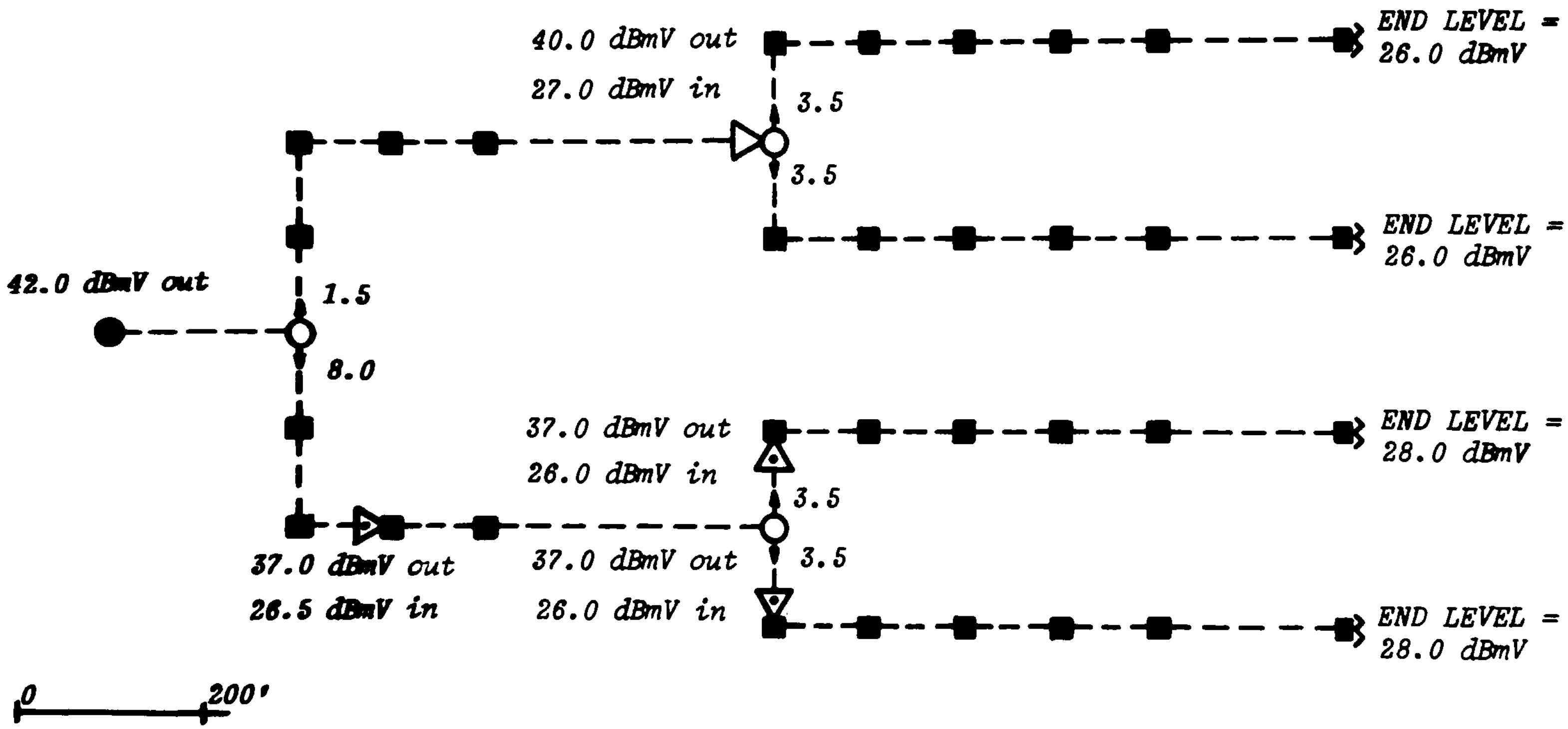


Figure 7
A manual design allowing 6 dB flat loss for taps.

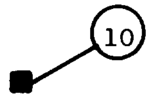
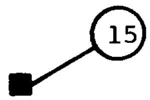
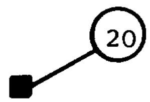
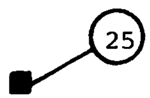
Tap Symbol	*Tap Loss at 270 mHz (dB)*	*Insertion Loss at 270 mHz (dB)*
	*10.0*	*1.5*
	*15.0*	*1.0*
	*20.0*	*0.5*
	*25.0*	*0.4*

Figure 8
Subscriber tap characteristics.

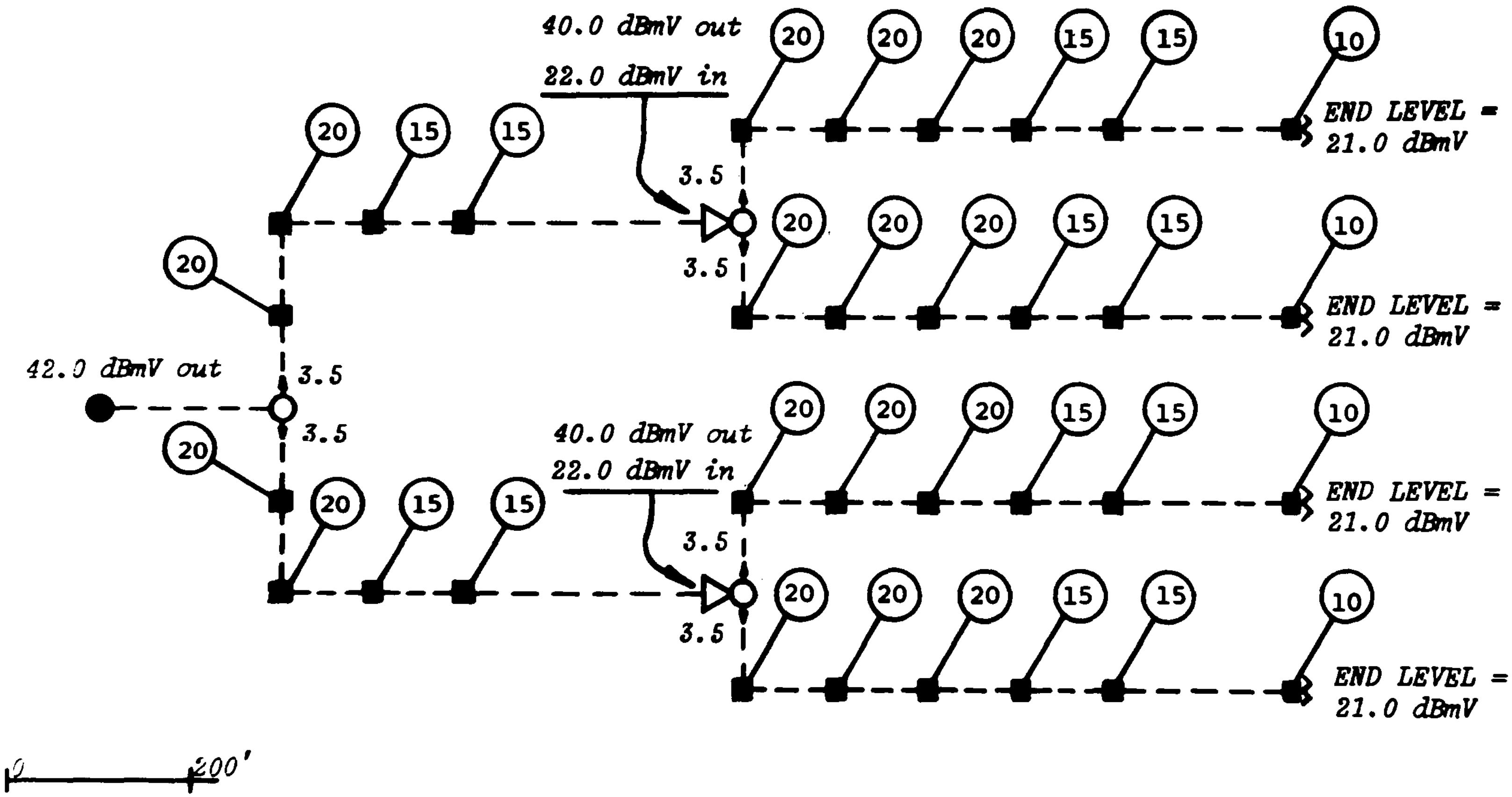


Figure 9
The computer design takes the tap characteristics into account in the optimization. The design above contains two less extenders than the manual design in Figure 7.