STAR-SWITCHED NETWORKS IN CABLE TELEVISION

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ABSTRACT

A star-switched system design for a cable television network is a departure from the conventional tree-and-branch network design in that it eliminates a large percentage of trunk-and-feeder cable and electronics by replacing them with a drop star network. Costly converter equipment is placed outside of the subscribers' homes. As a result of relocating the converter equipment, the cable operator has a simple and virtually theft-proof service system. A star-switched system has far-reaching economic and performance benefits for the cable system operator at a cost that is competitive with a conventional system.

INTRODUCTION

Star-switched system designs are the result of technological advancements that have been made in digital electronics and in the cable television industry. Star switching in the digital format has been used by the telephone industry for over 10 years. That industry has reaped the benefits of advanced systems that have provided reliability and decreased expenditures for plant materials and operations. The cable television industry is now where the telephone industry was 10 years ago. Moving to star-switched design will allow the cable television industry to profitably exploit its technological advantages.

There are three main benefits that make star-switching desirable. The first benefit is the immediate and quantifiable results of eliminating signal and premium service theft. The CATV industry loses approximately 500 million to 1 billion dollars per year in revenues to signal theft and many more millions of dollars to theft and abuse of in-home equipment. For this reason alone the use of star switching can be justified. The second benefit is the improved performance and cost savings inherent in a system design that employs less trunk and feeder cable and fewer active line electronics than a conventional tree-and-branch design. The third major benefit is the convenience that arises from placing the bulk of the converter equipment off the subscribers' premises. Money and time are conserved by making the equipment accessible to the cable company personnel all of the time. This eliminates service-scheduling problems that can currently plague cable operators.

Other far-reaching benefits are derived from integrating star switching and addressing within the same system. An addressable system expands the operators' capabilities to change, develop, and offer increased services; to develop billing, maintenance, and diagnostic schemes to aid the operator in developing better and cost-saving policies. The development of such policies is only limited by the operators' ingenuity, creativity, and ambition to develop them.

As with any new technology, its developer must prove its value to the market. The developers of star-switched networks have an advantage in that the soundness of this type of design has been proven by its use in the telephone industry. The focus must now be on the cost benefits to the operator. Certainly, as the technology advances, the cost effectiveness of star switching will tip the balances in its favor.

BASICS OF STAR-SWITCHING

The design currently favored by the CATV industry is the tree-and-branch. This is a series layout that is essentially an unbroken length of trunk cable that starts at the headend and goes through the entire franchise area to cover all the homes in the area. Signals are tapped off the trunk via feeder cables to service subscribers.

The star-switched approach is a parallel layout. The whole service or franchise area is divided into a number of smaller service areas. Each smaller service area is built around an independent hub that is tapped off the main network.

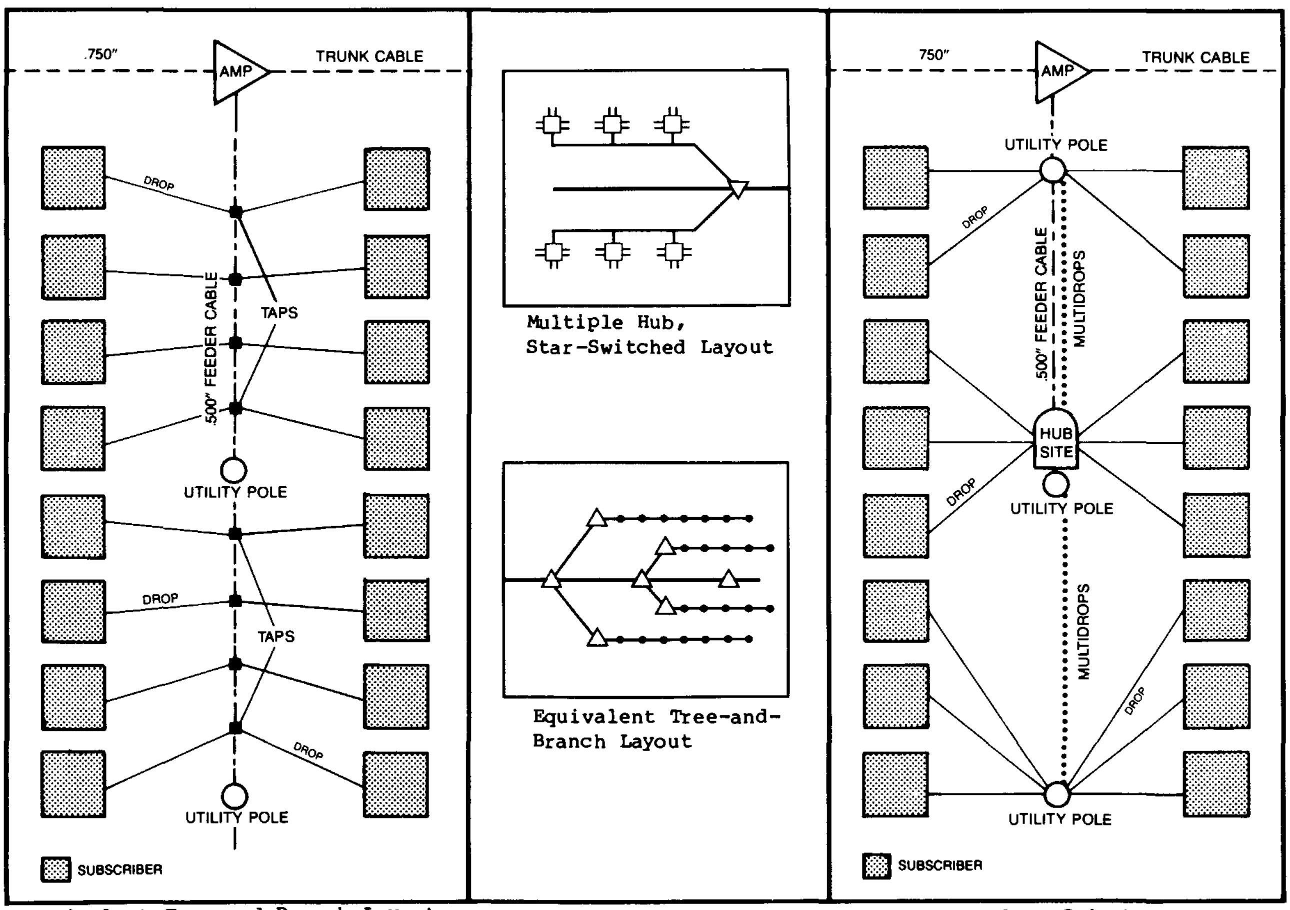
Radio Frequency signals (RF) are processed and distributed differently in the two systems; in a tree-and-branch design the full RF channel spectrum is transmitted over the entire backbone trunk and feeder. Drops are tapped off of the feeder and the full RF channel spectrum is sent to each subscriber. The subscriber's converter must then select a single channel from the full channel spectrum.

In a star-switched design, the full RF channel spectrum is delivered to each hub via the backbone trunk and feeder cable and not to the subscriber's residence. Economy is achieved because the full broadband RF spectrum is processed at the hub using a single high-quality, low-gain RF amplifier circuit. Only one RF channel low-frequency (two RF channels frequencies if a second set is used) at a time is authorized to leave the hub for the subscriber's residence. A digitally-based control circuit in the hub is the brain that directs the signals to each subscriber upon request. All channel and frequency conversion is performed at the hub, and only the firstand second-set channels are sent over the drop cable. For example, a channel change request is initiated by the subscriber. This request is transmitted upstream on the drop to the digital control circuit in the hub. The digital control circuit determines if that channel is authorized; if it is, the digital control circuit directs a remote switching unit to forward the channel downstream on the drop cable to the subscriber residence. Some drop cable problems may be avoided because of the single-channel, low-frequency RF transmission. Signal theft becomes impossible for anyone except the most perseverant because the conversion equipment is removed from the domain of the subscriber.

Figure 1 shows a typical layout for a star-switched and a conventional tree-and-branch design. In a star-switched layout, drop cables are not directly connected to the feeder lines as they are in a tree-and-branch layout. Rather, the hub serves as the junction point between the feeder cable and the drop cable. No taps are required in the feeder other than one that delivers 10 dBmV to the input of the hub. Instead, drop cables are first connected to the bottom of the hub enclosure or in some cases to a junction plate mounted near the hub then routed to the subscriber's residence using standard industry practices.

A star-switched system is comprised of three basic parts or equipment groups.

- o The headend group - this consists of the standard signal transmission equipment that is used to control the addressable portion of the system. For a one-way system (from the headend to the system only), an FSK generator is used; for two-way applications (back and forth from the headend to the system), a full two-way modem is added.



Multiple Hub, Star-Switched Layout

Equivalent Tree-and-Branch Layout

Equivalent Tree-and-Branch Layout

Single Hub, Star-Switched Layout

Figure 1

- The hubs (local distribution groups) - these are the links between the headend and the subscribers. Each hub contains the RF amplifier and distribution equipment, data processing equipment, channel switching equipment, and other optional and peripheral equipment used in the system. The hub also serves as the physical junction between the backbone trunk and feeder network and the subscriber drop cables.
- Subscriber group equipment - this final leg of the system consists of the drop cable that runs to the subscribers' residences and the interface unit with which the subscriber communicates with the hub. Often this equipment takes the form of a set-top interface unit and a hand-held remote unit which allows the subscriber added flexibility and convenience.

DESIGN CRITERIA

With this basic understanding of star-switched off-premises equipment and its configuration, the next step is to examine system design and layout.

A successful star-switched system is designed using the following parameters:

- System Bandwidth - typical systems up to 550 MHz
- Expected Penetration Rates - used to determine service area (cluster) size
- Strand Maps - used to determine the size of cluster service areas and the amount of cable for the trunk and feeder interconnect network

Once this information is gathered, the design follows a four-step process:

1. Identify the cluster service areas
2. Determine the optimum hub locations within the cluster
3. Design trunk and feeder RF interconnect to the hubs
4. Determine system powering requirements

Unlike a conventional design in which trunk is laid out and the feeder is routed to pass by virtually every residence, the star-switched design starts by first identifying the groups of residences to be serviced from each hub site within the franchise area. These groups of residences are referred to as clusters. Once the clusters have been identified, a point is chosen in each cluster where the hub is to be located. The optimum point location is one that minimizes the amount of drop cable required in the service area without exceeding the limitation of the drop cable from the hub to the subscriber. After these points have been established, the trunk and feeder interconnect network is designed.

The actual mapping or layout of the star-switched network should be considered in three parts--clustering, hub placement, and backbone cable plant layout. Satisfying the clustering and hub placement part of the design process requires an understanding of the relationship between cluster size, hub size, and the density of homes in the franchise area.

HUB LAYOUT

A cable franchise is divided into cluster service areas with each cluster containing one or more hubs. Generally, cluster size is dependent on home density, hub capacity, practical drop length, and financial limitations. Choosing too large a cluster size for a low density area results in high drop cable cost because of drop cable lengths that are too long. Choosing too small a cluster size minimizes drop lengths but results in a large penalty for the additional hubs and trunk and feeder cable necessary to serve a greater number of hubs than is really needed. Different hub sizes allow for expansion at a hub site if expected penetrations are exceeded after the initial design without disturbing other areas of the design.

First, the number of residences that can be serviced by a particular size hub must be determined. Several calculations are made based on projected percentages of subscriber penetration and subscriber service requirements (first set service and second set service) to determine hub capacity. Allowances can also be made for expansion in the hub if penetration, over time, exceeds original predictions. This is the most critical step in system design, because it determines the limits of cluster capacity. Examples of sample hub capacity calculations are shown in Exhibit 1 using the following formula:

$$\text{Capacity} = \frac{(H_S)(P_E)}{(1 + S_2)(S_1)} \qquad (1)$$

where:

- H_S = Total number of slots at the hub
- P_E = Packing Efficiency*
- S_2 = The percent of 2nd sets in the cluster area as related to total penetration (expressed in decimal form)
- S_1 = The percent of 1st sets in the cluster area as related to total penetration (expressed in decimal form)
- Capacity = Homes passed per enclosure for a cluster

* Packing efficiency is basically a growth factor. It is used to allow for additional slot space in a hub if growth is beyond the expected penetration rates. The more confidence that expected penetration rates will not be exceeded, the higher the packing efficiency should be. It is important to note that during initial construction only sufficient enclosure capacity needs to be planned; converter electronics can be added as a function of penetration.

EXHIBIT 1 - CALCULATING HUB CAPACITY

VARIABLES

- o 50% 1st set penetration (S_1)
- o 15% 2nd set penetration (S_2)
- o 90% packing efficiency (P_E) (allow 10% growth in hub enclosure after expected penetration is achieved)

Example 1 - 8-slot hub enclosure

$$\text{Capacity (No. homes passed per cluster/enclosure)} = \frac{(8)(.90)}{(1 + .15)(.5)} = 12$$

Example 2 - 16-slot hub enclosure

$$\text{Capacity (No. homes passed per cluster/enclosure)} = \frac{(16)(.9)}{(1 + .15)(.5)} = 25$$

Example 3 - 32-slot hub enclosure

$$\text{Capacity (No. homes passed per cluster/enclosure)} = \frac{(32)(.9)}{(1 + .15)(.5)} = 50$$

Once the hub size has been determined, the next step is to identify these cluster service areas on the strand maps. At this stage, the limiting factor that governs the size of the cluster is the peak length limitation of the drop cable out of the hub to the subscriber's residence. Table 1 shows the length limitations for both a drop powered and non-drop powered star-switched system, using a single drop cable. Note that there are different powering schemes available to the system designer. This variety allows the designer to choose a powering format based on economic limitations and operator preference.

POWERING OPTIONS

Powering options available to a star-switched network are summarized as follows:

110 VAC power - Each hub is connected to the power network through an electrical riser. This approach is best utilized in system designs that are of high-density and that have closely spaced hubs which service many subscribers, typically 48 or more subscribers per hub. Such builds are apartment buildings, housing developments, or institutional applications where 110 VAC is readily available for powering the hubs. The in-home interface equipment takes its power from the subscriber's electrical circuit.

60 VAC cable plant power - Each hub is powered from the 60 VAC that exists on the backbone cable plant. Whereas with the 110 VAC powering scheme each hub would require its own riser, and possibly its own meter, the ratio of risers and meters to hubs is much smaller here because 110 VAC meters and risers are only needed to serve each trunk power supply. In turn each power supply can serve up to 10 hubs, depending upon the capacity of each hub. This method is best suited to urban builds in which smaller hubs are spaced farther apart and serve a lower concentration of subscribers. This powering scheme is also well-suited for "garden apartment" environments where it may be economically unfeasible to run 110 VAC lines to each hub location. In these situations numerous meters and risers would not only be costly, but would also pose a maintenance problem. As in the 110 VAC approach, all hub equipment is powered by the 60 VAC. The in-home interface equipment takes its power from the subscriber's electrical circuit.

TABLE 1 - DROP DISTANCE LIMITATIONS

Cable Type	Non-Drop Powered Maximum Drop Length (Ft)			
	1 TV SET	2 TV SETS	1 TV SET & FM	2 TV SETS & FM
RG-59	1090	600	680	540
RG-6	1350	750	850	675
Cable Type	**Drop-Powered Maximum Drop Length (Ft)**			
RG-6	1280	640	850	640

60 VAC cable plant powering/drop powering - Two separate power services serve each hub. The common hub electronics (RF amplifier, digital control circuit, and peripheral equipment) are powered by the 60 VAC the same way as in the straight 60 VAC method. The in-home interface equipment for each television set is powered by 30 VAC which is generated from the subscriber's power circuit. This approach eliminates the variable power consumption problem caused by the remote switching modules which are designed to be powered on and off along with the subscriber's television set. A constant and predictable load on the trunk allows the designer to load each cable plant power supply to capacity for most efficient operation. Drop lengths are especially critical here because of the increased power loss inherent in long runs. Depending on the size of the drop cable, the drop length may be limited by AC power loss as opposed to RF power loss.

SYSTEM COMPARISON

With an understanding of how a star-switched off-premises design is laid out and the relative differences from a conventional tree-and-branch system, the next topic is the actual equipment impact a star-switched design has over a conventional design.

Table 2 shows a comparision of trunk and feeder equipment for a standard tree-and-branch system and a star-switched system. These numbers were obtained from an actual sample design for a metropolitan build.

TABLE 2 - PLANT MATERIAL DESIGN AREA
(23.28 plant miles, 6843 homes passed)

	CONVENTIONAL	STAR-SWITCHED
Trunk Amplifiers	36	18
Line Extenders	124	27
Passives	1,218	944
Hubs	0	220
Connectors Trunk/Feeder	2,002	901
Drop Connectors	0	14,000
Cable		
500	121,270	89,623
750	35,671	24,432

The same geographic area is covered in both designs. The difference in the Bill of Materials is a result of the following:

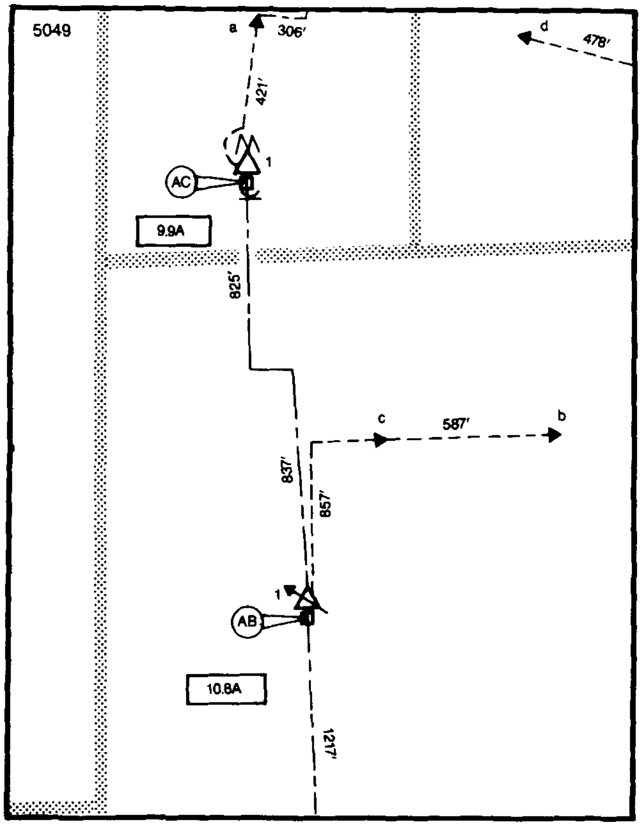
Each hub requires 10 dBmV input to service up to 32 subscribers or about 30 to 50 homes passed, depending on the expected penetration, which effectively replaces feeder line taps and feeder cable. Directional couplers feed the hubs so more reach is accomplished in the feeder lines because there is no flat insertion loss of taps thus more system reach is available without the use of many line extenders. The balance of the feeder leg coverage is accomplished with a 100 percent dedicated drop for each home passed or drops can be added incrementally with penetration. Of course, the approach taken for drop cabling depends on operator preference and various economic considerations. The main difference in the trunk amplifiers is that few, if any, trunk splits are required off the main cascades. Figure 2 shows a sample portion of the strand maps for the geographic service area described in Table 2. Both maps cover the same geographic service area. In both designs, feeder legs that do not have line extenders are not shown. The main cascade usually requires about 20 percent less trunk stations for the same geographic coverage; the total number of system trunk stations is usually about 50 percent less than in a tree-and-branch design.

SUMMARY

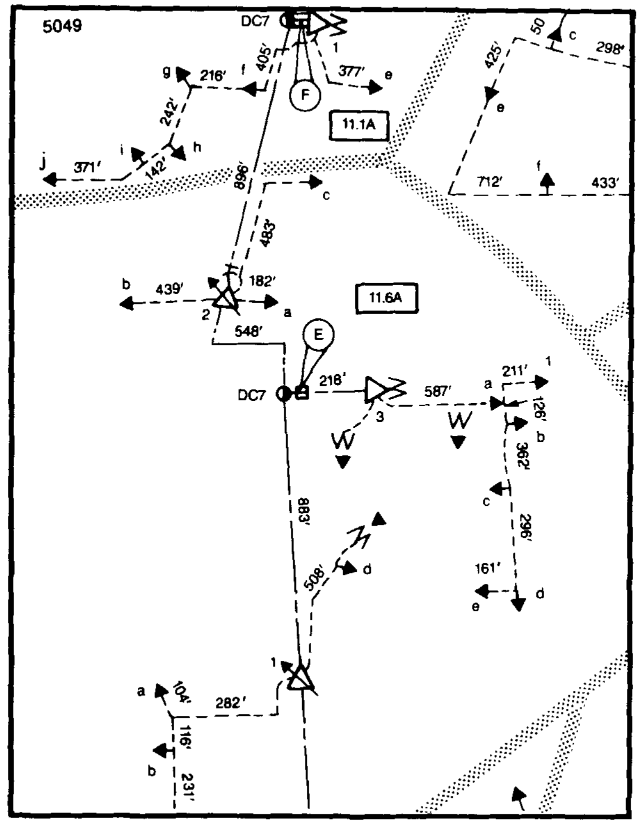
The rules for designing a star-switched system differ from those used to design a conventional tree-and-branch system. The emphasis in a star-switched system is placed on a set of criteria that allows the system designer many options in choosing his approach. Subdividing the whole franchise area allows each division to be designed and built separately, while still being controlled centrally. The impact of system expansion is limited to the areas that are expanding and not the entire system. The net effect of a star-switched system's design and operating features is simplicity and security. These are due primarily to the following:

- Fewer trunk and feeder system electronics in the total design.
- Considerably less trunk and feeder plant running the full 350 or 550 MHz spectrum in the franchised service area.
- No "tap-feederline" design calculations required at each pole location where there are potential subscribers.
- Interchangeable powering methods which allow the operator to choose the right method in the right location.
- Subscriber converter equipment located off-premises.

Experience has shown that the star-switched systems of today can be easily designed and can perform comparably to conventional addressable/ scrambled cable systems at a competitive price.



Strand Map Section - Star-Switched Layout



Strand Map Section - Tree-and-Branch Layout

Figure 2