MULTI-LAYER HEADEND COMBINING NETWORK DESIGN FOR BROADCAST, LOCAL, AND TARGETED SERVICES

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Abstract

In modern hybrid fiber-coaxial (HFC) networks, the target subscriber groups for various signals originating from headends and hubs are different. Some of the signals are of broadcast type destined to all customers, the others target a limited number of customers. These differences must be reflected in the design of the headend/hub combining/splitting networks to take advantage of spectrum re-usability.

This paper describes headend and hub combining/splitting networks designed to meet the new requirements of narrowcast and targeted services. It also presents a combining/splitting network for reverse signals that require a distinctly different approach from the forward signals.

GENERAL

Headends and hubs serve as major signal sources and processing centers in hybrid fiber-coaxial networks. The quality of signals originating from these centers is a reference line for the quality of signals delivered to our customers. These signals will never be better than at these origination points.

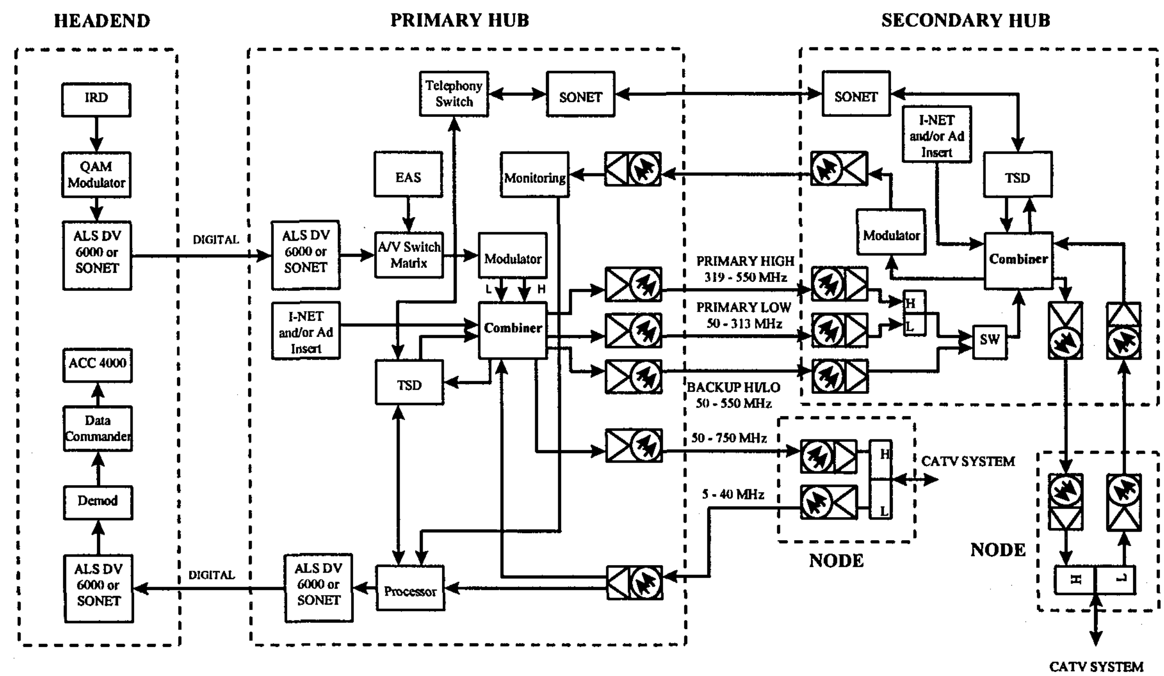
Due to the complex character of the modern headends and hubs and their critical impact on network availability and signal quality, an adequate design for all headend and primary hub forward combining/splitting networks is extremely important. Headend reverse combining network design should be flexible enough to accommodate new services. This should be achieved without future service disruptions.

To enhance the flexibility of the design, the combining/splitting network is divided into sublevels. Each sublevel is designed independently of the other sublevels, with precisely defined interface parameters for compatibility. Headend and primary hubs include combining/splitting networks with a maximum of four functional sublevels. The number of sublevels at a particular location depends on the output level from optical receivers and on the number of optical nodes served by the hub.

SIGNAL ACQUISITION AND PROCESSING CENTERS

The HFC network is supported by processing and routing equipment grouped in headends and hub facilities. These facilities are categorized as headends, primary hubs and secondary hubs depending on their function and location.

Figure 1: Headend Configuration — Example



The headend serves as an entry point in the primary hub ring and may include proprietary or SONET transport system interfaces. Satellite signals and signals from other sources are received here, processed and distributed to the other sections of the system.

The primary hub functions as an acquisition, modulation, combining, and distribution center in the primary hub ring. The primary hub may also deliver signals to the secondary hub ring using fiber transport systems, and to the optical nodes served directly from that primary hub. Once signals are received from the primary hub ring, they are routed to modulators and then into the combining system. Signals originating from other sources also enter the forward combining system. Reverse data, telephony, status monitoring and PPV signals are processed, combined, and routed to their destinations.

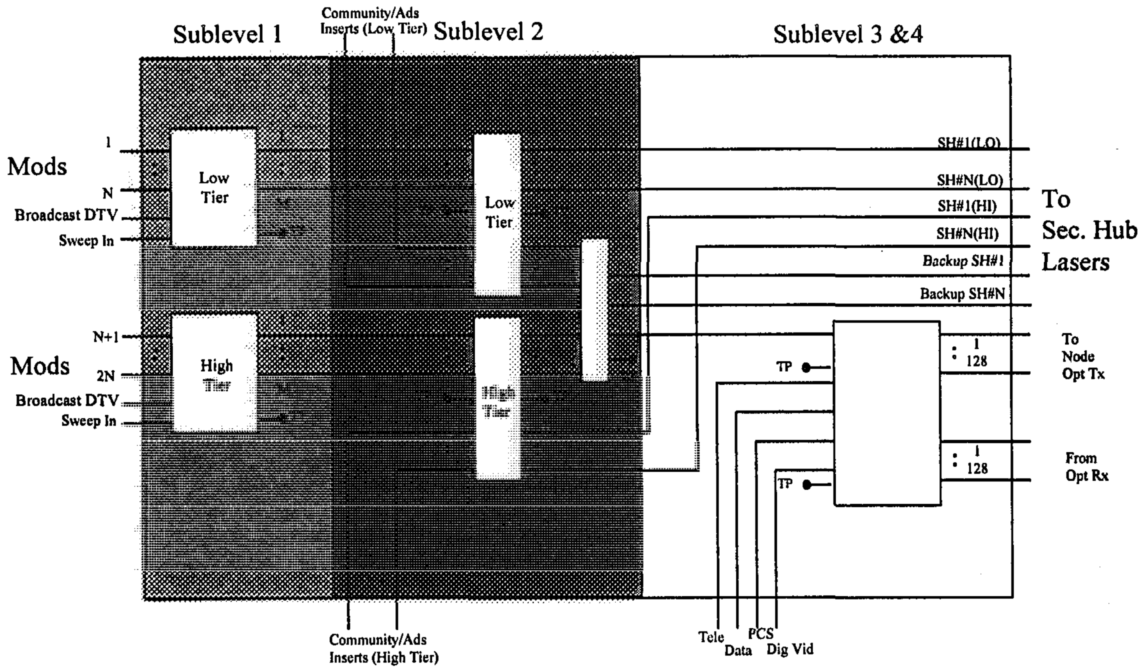
The secondary hub interfaces to the secondary hub ring and serves local nodes. Redundancy switching precedes combining. Telephony and data signals interface through the targeted service delivery access points. Monitoring signals also flow through the secondary hub on their way to the primary hub.

A particular HFC network may not include all these facilities depending on size of the market and alternative architecture design but most will contain at least two elements in large and medium size markets.

FUNCTIONAL DESCRIPTION

The headend and primary hubs include a combining/splitting network with up to four functional sublevels (see Figure 2). The secondary hubs include a combining/splitting network with two or three functional sublevels. The number of sublevels depends on the function of the secondary hub, signal processing complexity and on the number of optical nodes served.

Figure 2: Combining/Splitting Network — Overview



Sublevel 1

Sublevel 1 will function as an input combining/splitting unit. It uses a dual-tier approach with low and high tiers. Two optional combining configurations and two optional splitting configurations exist. The choice of the optimal combination of the configuration depends on the type of modulator bank used and on the number of secondary hubs served from the location. The following recommendations will help in the selection of the appropriate input combining option:

1. Input combining Option 1 combines up to 6 pre-combined modulator inputs for a total of 48 modulators or other signal sources per tier. This option is recommended for all applications with manufacturer-pre-combined modulators. Modulators are usually pre-combined to manage spurious and out-of-band noise that can be dominant in agile units. In many cases where local ad insertion is required, empty slots will be left in the pre-combined channel groups to accommodate the local channel insertion in Sublevel 2.
2. Input combining Option 2 allows for combining of up to 48 single modulators or other signal sources per tier.

In both cases, two additional inputs in each tier can be used for combining sweep signals and broadcast digital TV signals.

The following recommendations will help in the selection of the appropriate output splitting option:

A. Output splitting Option A provides up to 7 outputs for each tier and serves up to three secondary hubs (both principal and back-up feeds) and local optical nodes. If the local nodes are not served from this primary hub, an additional secondary hub can be served (total of 4).
B. Output splitting Option B of Sublevel 1 provides up to 15 outputs and serves up to seven secondary hubs (both principal and back-up feeds) and local optical nodes. If the local nodes are not served from this primary hub, an additional secondary hub can be served (total of 8).

Sublevel 2

Sublevel 2 functions as an ad insertion combining unit for both the low and high tiers. Sublevel 2 additionally provides signal amplification. It has a backup combining unit in case the principal Sublevel 2 combining unit fails. Moreover, Sublevel 2 provides combining network for local distribution to optical nodes.

Sublevel 3

Sublevel 3 provides splitting and amplification network for feeding up to 128 optical nodes directly from the primary hub. It also combines TSD service signals with broadcast and local signals from Sublevels 1 and 2. Sublevel 3 network is also implemented in secondary hubs after the redundancy switch (see Figure 1).

Sublevel 4

Sublevel 4 provides combining network for targeted service delivery signals in the forward direction and splitting network for target service delivery signals from the reverse path optical receivers.

SIGNAL COMBINING/SPLITTING NETWORK — DETAILS

Sublevel 1 (Figure 3)

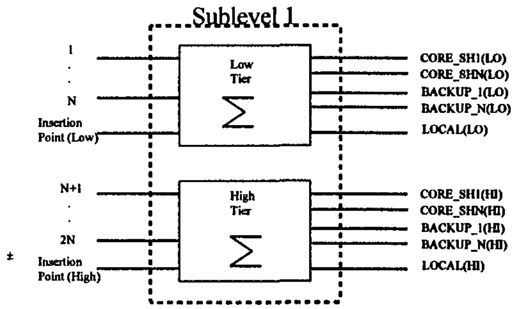
Almost all elements in this level of the combining network are non-redundant. All components, except for the first combining gear following the modulators and the last attenuator before pre-amplifiers in Sublevel 2, are shared among all customers served by the headend/primary hub. The purpose of this sublevel is to combine signals from all broadcast sources, including broadcast digital TV, and split the combined signals to feed the secondary hubs and local optical nodes.

Design Objectives

The following objectives should be achieved:

1. Sublevel 1 section of the network must be designed for all future expansion in the number of secondary hubs served. Future reconfiguration should not cause service disruption.
2. All elements must be reliable and be assembled and cabled to achieve the highest possible level of reliability. Only approved elements should be used. The number of connectors must be limited and cables kept as short as possible.
3. Output levels of Sublevel 1 must be optimized to minimize distortion introduced by Sublevel 2.

Figure 3: Sublevel 1 of Combining /Splitting Network



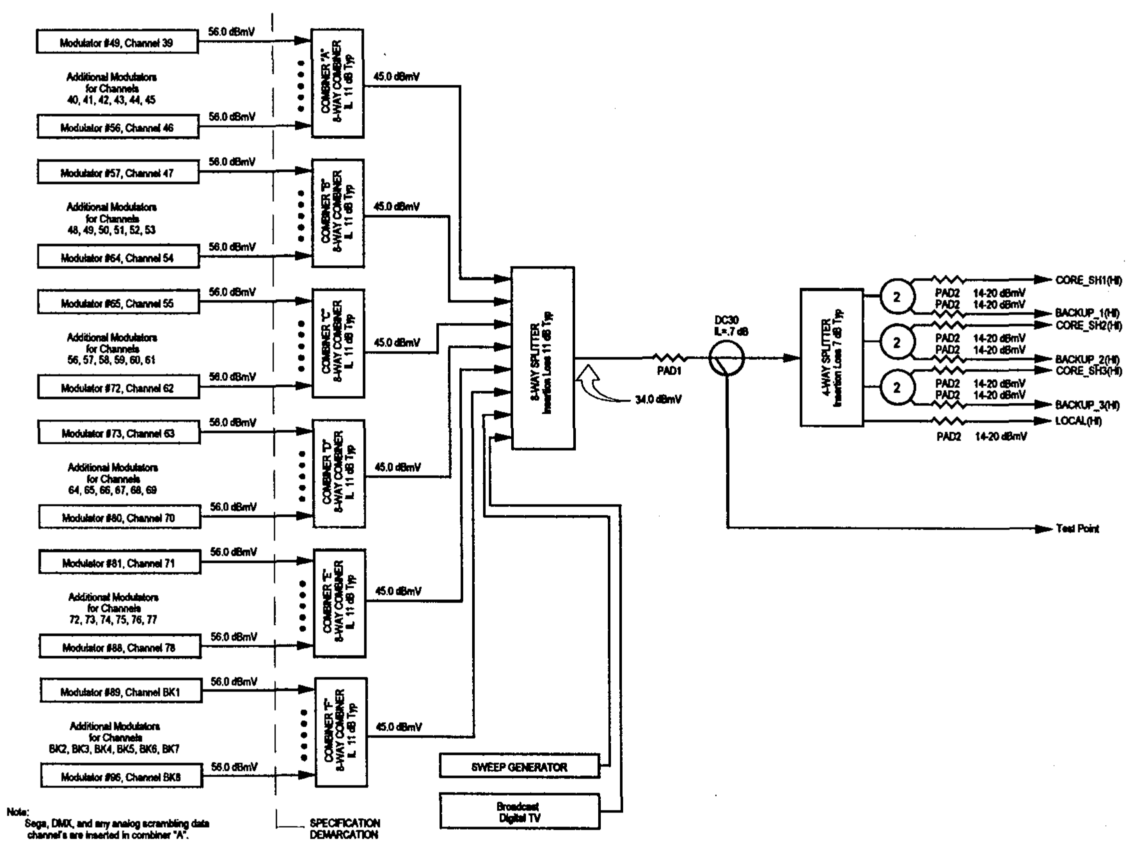
Detail Description — Input Combining Options (see Figure 4)

Low tier combining serves channels 2 through 38, and high tier combining serves channels 39 through 78. A single tier of Option 1 input combining in Sublevel 1 combines input from up to 6 pre-combined sources. A single tier of Option 2 input combining combines outputs from up to 48 single modulators or other sources. In Option 2, the combining is achieved by two layers of 8-way combiners.

NOTE 1: In Option 2, channels into the first layer of combining should be arranged in a non-consecutive order to minimize spurious generated in the output stages of the modulators.

NOTE 2: Output signal levels from modulators should be pre-emphasized to account for diplex filter crossovers.

Figure 4: Sublevel 1 — Example: High Tier Combining Using Single Channel Modulators Feeding 3 SH Lasers (Option H2A)



Broadcast digital TV signals are pre-combined for an equivalent of up to 16, 24, or 32 analog channels (96, 144, or 192 MHz). The pre-combining is achieved with 8-way combiners followed by a 2-way, 3-way (balanced) or 4-way combiner. These signals are combined with the analog broadcast signals in Sublevel 1. The combining is achieved through a spare input of the 8-way combiner. The digital signal levels (average power per channel) at the output of Sublevel 1 combining network are set to the required level in relation to the analog signal levels (peak-value). These levels can be set by inserting a pad of an adequate value before combining with the analog channels.

NOTE 3: If any of the digital TV signals occupies a channel between 2 and 78, it can be injected in the combining network in place of that analog channel at an adequate level as per the design for the particular system.

A sweep generator is directly coupled to one of the 8-way combiner spare inputs.

Detail Description — Output Splitting Options (see Figure 4)

The signals are next directed to a splitting section of Sublevel 1 via an optional pad (usually omitted) and 30 dB forward test point coupler. Two different options exist in the splitting section: Option A serves 3 secondary hubs and a number of local nodes, and Option B serves 4-7 secondary hubs and a number of local nodes.

NOTE 4: Future removal or replacement of the attenuators due to level requirements would result in service disruption. Hence, it is recommended that PAD1 not be placed.

In Option A, the combined signal from each tier is fed to a dedicated 4-way splitter. Three outputs of this splitter are split again and the outputs of the 2-way splitters feed principal and backup sections of Sublevel 2 via dedicated attenuators (PAD 2). The last output feeds pre-amplifiers of Sublevel 2 local node links via level adjusting attenuators (PAD 2). If no local optical nodes are served from the primary hub, the number of secondary hubs served can be increased to four.

Option B is similar to Option A with the 4-way splitters replaced with 8-way splitters.

NOTE 5: If the current or anticipated number of secondary hubs served is higher than 3, use only 8-way splitter (splitting Option B) in the splitting section of Sublevel 1.

Detail Description — Output Level Alignment (see Figure 4)

Sublevel 1 output levels should be within 17 dBmV ± 3 dB. For low gain pre-amplifiers (17 dB), they should be as close as possible to 20 dBmV. For high gain pre-amplifiers, output levels should be as close as possible to 14 dBmV. Guidelines for using low or high gain pre-amplifiers are presented in the description of Sublevel 2. The levels are adjusted with PAD 2 attenuators.

NOTE 6: Future removal or replacement of the attenuators in PAD 2 location of the local optical node (ON) path would result in service disruption. Hence, it is recommended that this attenuator value be selected based on the current and anticipated number of optical nodes served. The attenuators on SH paths are redundant.

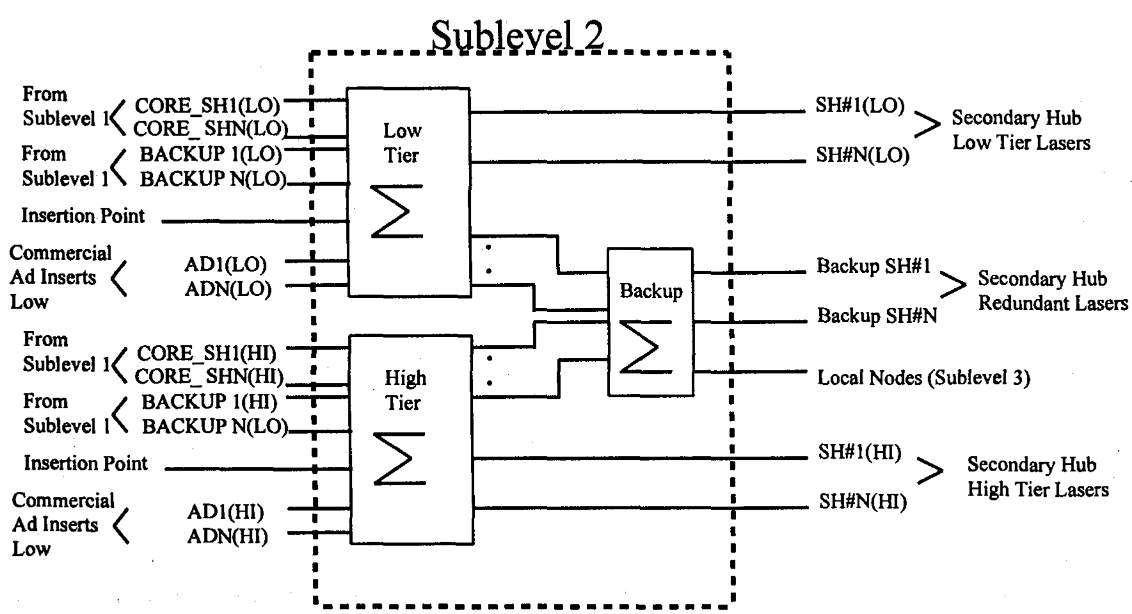
Table 1: Design Choices — Sublevel 1

Network Elements	Choices	Selection Criteria	Note #
Input combining network for analog signals	Option 1	Pre-combined modulators	
	Option 2	Single modulators in primary hubs	
Input Combining network for digital TV signals	Combined through an 8-way combiner	Frequency allocation above analog channels	
	Injected directly as analog modulators	Frequency allocation between analog channels	Note 3
Pad value in PAD 1	0	Level requirements	Note 4
Output splitting network	Option A	For 3 secondary hubs and up to 128 local nodes served or for up to 4 secondary hubs served	
	Option B	For up to 7 secondary hubs and up to 128 local nodes served or for up to 8 secondary hubs served	Note 5
Pad value in PAD 2 in local ON path	Lowest possible	Low input lasers, Sublevel 1 output ≤20 dBmV	Note 6
	Highest possible	High input lasers, Sublevel 1 output ≥14 dBmV	Note 6

Sublevel 2 (Figure 5)

The elements of this level of the combining network are redundant for secondary hub links but are not redundant for local optical node links except for the pre-amplifiers for optical nodes. The purpose of this sublevel is to amplify the combined broadcast signal to levels adequate for secondary hub lasers or for Sublevel 3 in optical node section. Sublevel 2 in secondary hub section allows for inserting signals targeted to a particular community (ad inserts, local programming, and other community targeted services). Sublevel 2 also combines tiers in back-up secondary hub and optical node sections. The tier combining can also be performed in principal secondary hub sections if the design calls for single-fiber principal secondary hub links. However, the tier configuration is maintained even in this case to lower the distortion contribution of the combining network amplifiers.

Figure 5: Sublevel 2 of Combining /Splitting Network



Design Objectives

The following objectives should be achieved:

1. Sublevel 2 section of the network must be designed for adequate levels to the secondary hub lasers and to Sublevel 3 for local ON.
2. Optical node section of Sublevel 2 must be designed for all future expansion in the number of optical nodes served. Future reconfiguration should not cause service disruption.
3. Output levels of Sublevel 2 in the optical node section must be optimized to minimize distortion introduced by Sublevel 3.
4. All elements must be reliable and be assembled and cabled to achieve the highest possible level of reliability. Only approved elements should be used. The number of connectors must be limited and cables kept as short as possible.
5. Active elements of Sublevel 2 must be selected to minimize distortion.
6. The design of the secondary hub section of Sublevel 2 must provide adequate isolation between local programming signal sources.

Detail Description — SH Principal and Back-Up Amplification (see Figure 6)

The input signals from Sublevel 1 are amplified to the level adequate for the secondary hub link laser inputs. The gain of the amplifier should be higher for lasers that require a higher input level in order to achieve adequate isolation between local distribution signals. The amplifiers are followed by attenuators in PAD 3 locations. The values of the attenuators are maximized to achieve the required isolation between local ad insertions and local programming for different optical links. The attenuators are followed by directional couplers for local ad insertions and local programming, and by DC-30 test points. These test points serve as reference points for signal flatness alignment for the entire headend/hub. For single-fiber principal secondary hub links, diplex filters for tier combining are installed before the test point couplers. Since back-up links are a single-fiber type by design, diplex filters for tier combining are always installed.

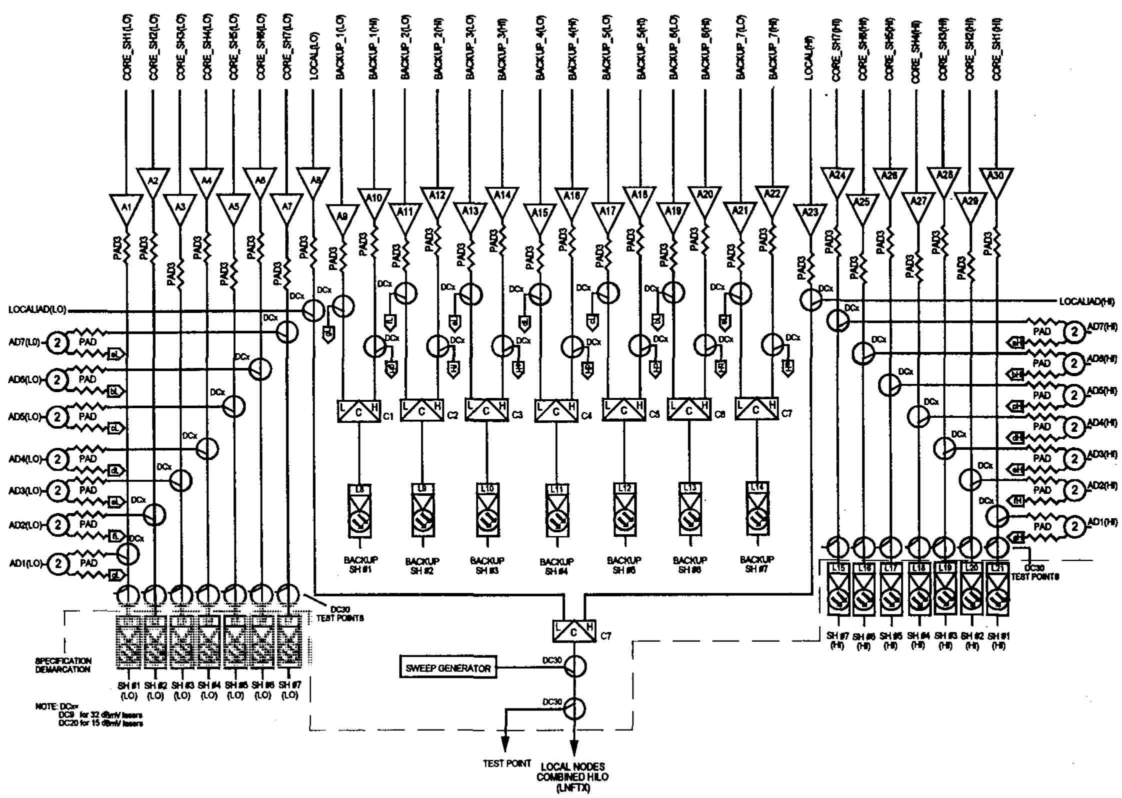
NOTE 7: The tier arrangement is maintained even in the case of single-fiber principal secondary hub links to minimize the loading of active components of the combining network and noise accumulation from modulators and active components.

Detail Description — Optical Node Link Amplification (see Figure 6)

The input signals from Sublevel 1 are pre-amplified to the level adequate for the Sublevel 3. The gain of the amplifiers is higher (not higher than 21 dB) in hubs that feed more than 32 optical nodes with ON lasers that require higher input level. The amplifiers are followed by attenuators in PAD 3 locations. The values of the attenuators are maximized to achieve the required isolation between local ad insertions and local programming for different optical links. The attenuators are followed by directional couplers for local ad insertions and local programming. After the couplers, the signals from the two tiers are combined with diplex filters. The diplexers are followed by DC-20 sweep insertion and DC-30 test points.

NOTE 8: Amplifiers in local optical node links should be configured in a parallel setup or be redundant (with A/B output switching). They should be also monitored for failure. These amplifiers may serve tens of thousands of customers.

Figure 6: Sublevel 2 — Example: High/Low Tier Combining Feeding 7 Secondary Hubs



Detail Description — Local Community Programming & Ad Combining Network

Local service signal combining network consists of 8-way combiners followed by 2-way combiners. The 2-way combiner cannot be used for ad inserts if the lasers in the secondary hub links require 32 dBmV or higher input level. The combined signals are fed into two-way splitters (splitting for principal and back-up links). No splitter is required for optical node links. The outputs of the splitters are followed by attenuators for independent level adjustment to the optical lasers. After attenuation, the signals are combined with the broadcast signal using directional couplers (DC-9). Broadcast or local digital TV signals can be inserted at this point to a community.

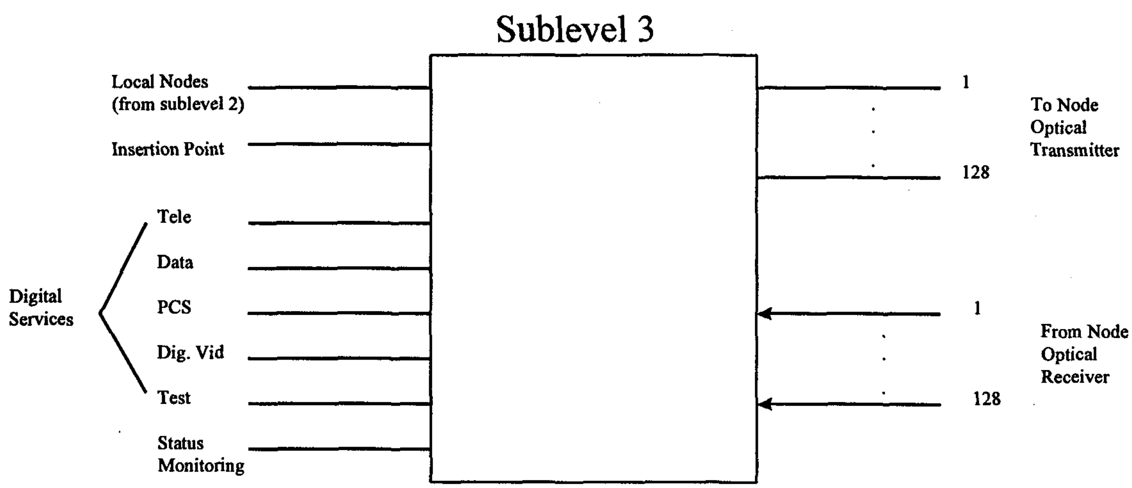
Table 2: Design Choices — Sublevel 2

Network Elements	Choices	Selection Criteria
Pad value in PAD 3	Highest possible	Level required at the laser input or at the input to Sublevel 3
Combining network for local ad inserts and programming	16 or 8 channels per tier	Level required at the laser input
Diplexer in principal SH links	In primary or secondary hub	Performance of the secondary hub lasers either allow or not allow for single-fiber principal SH links
Amplifier gain	17 dB or 21 dB	The number of secondary hubs and optical nodes served, and the input level requirements of the optical node lasers (17 dB gain amplifiers are sufficient in all situations where all lasers require no more than 18 dBmV input)

Sublevel 3 (Figure 7)

The elements of this level of the combining network are not redundant. The purpose of this sublevel is to split and amplify the combined broadcast and local signals to provide an adequate number of outputs and sufficient input levels to optical node lasers. Sublevel 3 allows inserting target delivery service signals and digital TV signals to a particular node.

Figure 7: Sublevel 3 of Combining /Splitting Network



Design Objectives

The following objectives should be achieved:

1. Sublevel 3 section of the network must be designed for adequate levels to the optical node lasers.
2. First splitting section of Sublevel 3 must be designed for all future expansion in the number of optical nodes served. Future reconfiguration should not cause service disruption.
3. All elements must be reliable and be assembled to achieve the highest possible level of reliability. Only approved elements should be used. The number of connectors must be limited and cables kept as short as possible.
4. Active elements of Sublevel 3 must have sufficient bandwidth capacity and be selected and aligned to minimize distortion.

Detail Description — Input Splitting (see Figure 8)

Signals from Sublevel 2 are fed into an 8-way splitter and then directly into amplifiers (for 32 optical nodes) or into 2-, 3- , or 4-way splitters for up to 64, 96, or 128 optical nodes served.

Detail Description — Amplification for ON Lasers (see Figure 9)

The outputs are fed into single- or dual-output pre-amplifiers followed by four- or two-way splitters if required. The gain of the amplifiers will be defined by the input level requirements of the optical node lasers. Next, the signals are routed to the optical node lasers via attenuators and TSD-insertion directional couplers followed by 30 dB test point couplers.

Detail Description — TSD Combining (see Figure 9)

The TSD signals from different service terminals are combined using 8-way combiners. The outputs of the combiners are fed to the insertion couplers via 30 dB test point couplers.

Figure 8: Sublevel 3 — Example: Local Node Configurations for 32, 64, 96, and 128 Laser Nodes

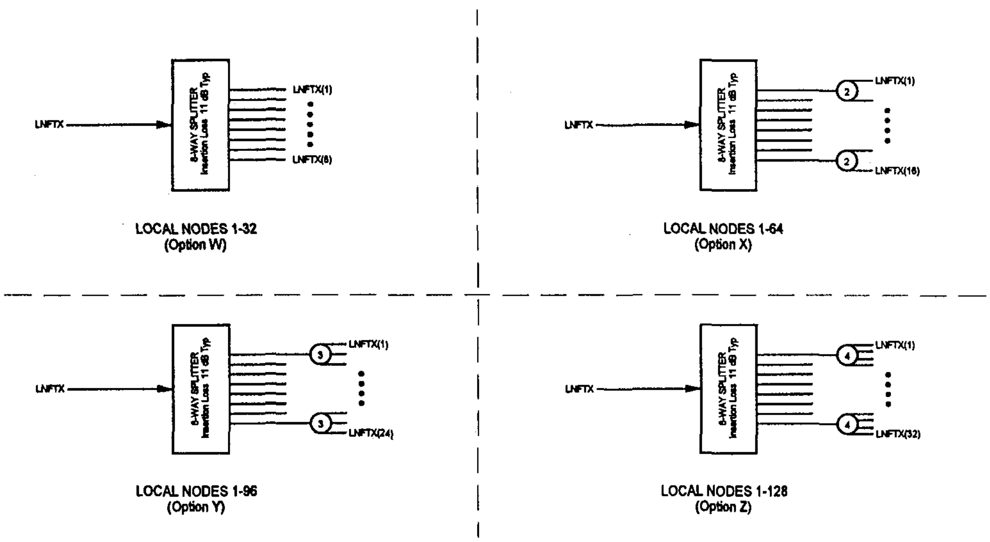
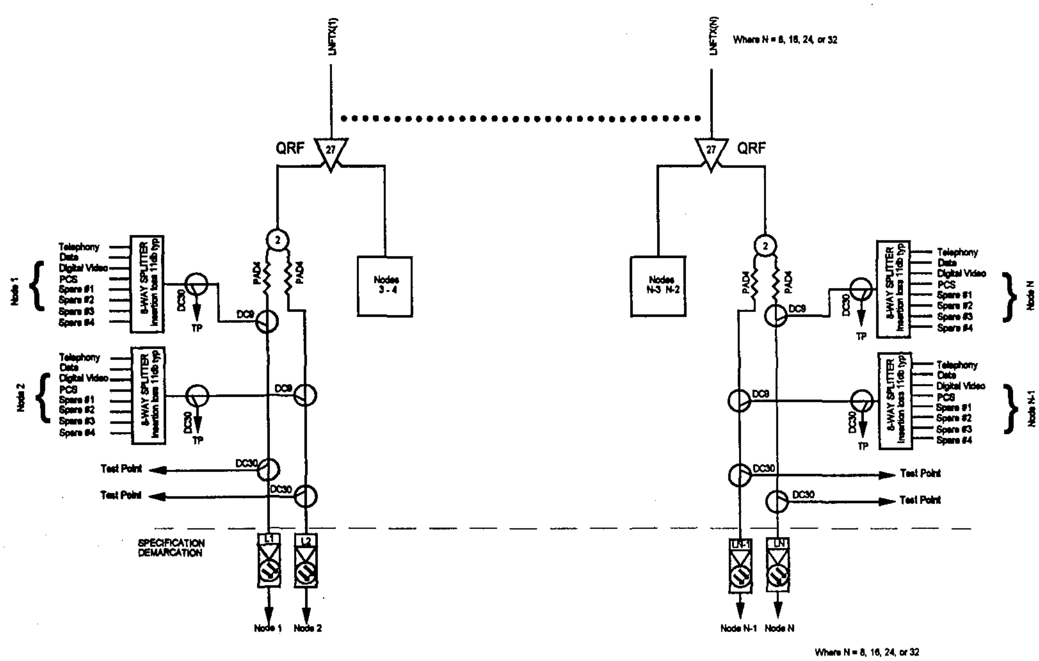


Figure 9: Sublevel 3 — Example: 96 Node Fiber Distribution



Option	Inputs	Outputs
W	8	32
X	16	64
Y	24	96
Z	32	128

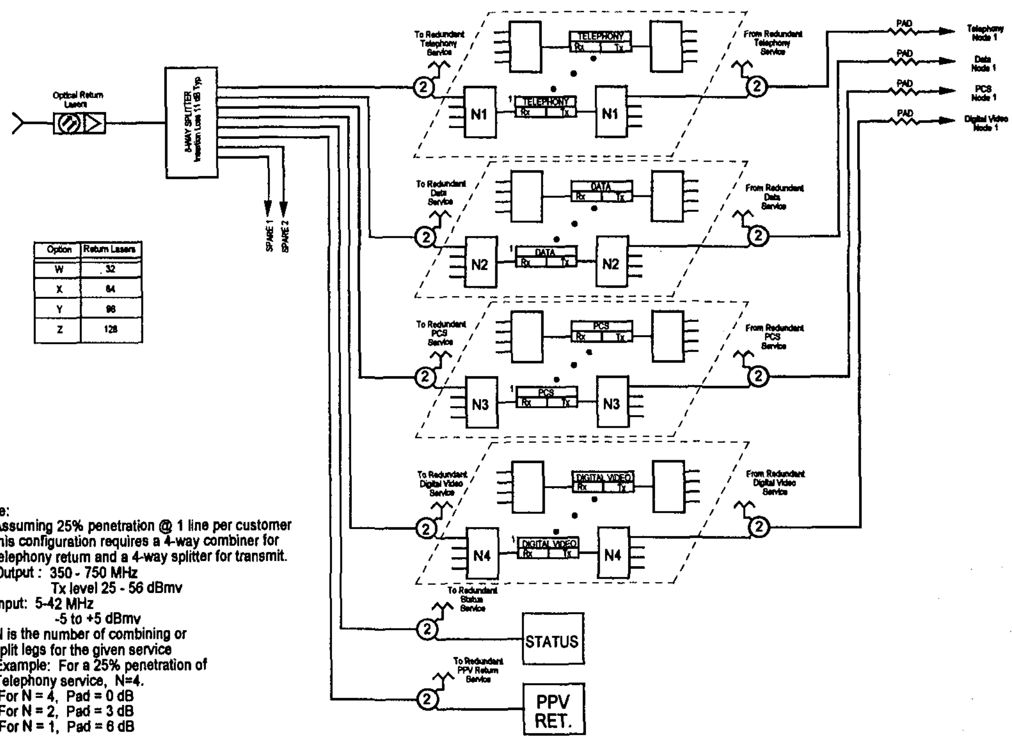
Table 3: Design Choices — Sublevel 3

Network Elements	Choices	Selection Criteria
Input splitting network	8, 16, 24, or 32 outputs	The number of optical node links served from the primary/secondary hub
Amplifier gain for local optical node links	17 dB or 25 (27) dB	The input level requirements of the optical node lasers (17 dB gain amplifiers are sufficient in all situations where all optical node lasers require no more than 18 dBmV input)
Pad value in PAD 4	Highest possible	Level required at the laser input

Sublevel 4 (Figure 10)

The elements of this level of the combining network are not redundant. However, each individual service combining/splitting network contains two splitters (one for forward and one for reverse) for non-disruptive network rearrangement. The purpose of this sublevel is to combine or split the targeted service delivery signals in the reverse and forward directions dependent on traffic engineering.

Figure 10: Sublevel 4 — Example: Return Path Combining



Design Objectives

The following objectives should be achieved:

1. Sublevel 4 section of the network must be designed for adequate levels to terminal equipment (reverse direction) and to optical node lasers (forward direction).
2. The network reconfiguration causing service disruption to all customers served by local optical nodes are limited to a replacement of the faulty elements.
3. The elements of the section must be reliable, and assembled to achieve the highest possible level of reliability. Only approved elements

should be used. The number of connectors must be limited and cables kept as short as possible.

4. Adequate isolation between target service delivery signals received from and directed to different target customer groups must be achieved.

Detail Description — Input Splitting in Reverse Path

Signals from reverse optical node receivers are fed into an 8-way splitter followed by 2-way redundancy splitters. After the two-way splitters, the signals are fed into individual service's terminal equipment.

Detail Description — Output Combiner

The outputs of individual service's terminal equipment are fed into a 2-way combiner via a splitting network. The outputs of the two-way combiners interface with Sublevel 3.

INPUT/OUTPUT SPECIFICATIONS

The following paragraphs present a short summary of the extensive analysis performed to optimize levels and allow seamless interface between the sublevels.

Sublevel 1 I/O Specifications

Input Combining Option 1

Pre-combined modulator output levels should be set at 43.0 dBmV. The minimum input CNR to the Sublevel 1 combining should be 65.0 dB. Spurs should be no greater than -65.0 dBc and the isolation minimum of 20.0 dB port-to-port.

Input Combining Option 2

Analog modulator output levels are nominally set to 56 dBmV. This setting allows for a frequency response alignment margin. The minimum input CNR from the modulators should be 67.0 dB. Spurs should be no greater than -65.0 dBc and the isolation minimum of 20.0 dB port to port.

Broadcast Digital TV Signals

Digital up-converter output levels are nominally set to 56 dBmV.

Output Signal Performance

A minimum of 63 dB CNR shall be achieved at the input to Sublevel 2 with spurs no greater than -65 dBc and a minimum isolation of 20.0 dB port to port. The levels shall be within 17 dBmV ±3 dB.

Table 4: Input/Output Specification for Sublevel 1

	Inputs		Outputs	
Options	**Option 1**	**Option 2**	**Option A**	**Option B**
Parameter				
Number of total analog inputs or outputs	12 with pre-combined modulators	96	16 or 18	32 or 34
Number of ports per tier	6	48	8 or 9 (3 or 4 principal, 3 or 4 back-up, 1 or 0 local ON, TP)	16 or 18 (7 or 8 principal, 7 or 8 back-up, 1 or 0 local ON, TP)
Number of additional ports (sweep, DTV) per tier	2	2		
Analog TV levels	43 dBmV	56 dBmV	17±3 dBmV	17±3 dBmV
Broadcast DTV levels*	33-37 dBmV	35-39 dBmV	6-10 dB lower	6-10 dB lower
CNR	65 dB	67 dB	63 dB	63 dB
Spurious	-65 dBc	-65 dBc	-65 dBc	-65 dBc
Port-to-port isolation	20 dB	20 dB	20 dB	20 dB

* At the input to the 8-way combiner.

Sublevel 2 I/O Specifications

Pre-Amplification

Input levels are predetermined by Sublevel 1 of the combining/splitting network. These levels are optimized for the CNR and distortion performance. The signals are then pre-amplified by high quality power doubling or feedforward amplifiers working at light loading (half of the 77 or lower channel loading) for better distortion performance. The pre-amplifiers' main purpose is to provide for an adequate isolation between local programming signals injected into different optical links. For example, the isolation (more accurately, the ratio of wanted to unwanted signals) between the local signal injected into the laser that requires 32 dBmV input and the local signal injected into another laser may be lower than 50 dB if the attenuator values are low (for low gain amplifiers) and their locations are not selected in an optimal way. The isolation between the local signal injected into the laser that requires only 15 dBmV input and the local signal injected into another laser may, on the other hand, be as high as 85 dB. Amplifiers of higher gain will be required for the high input lasers. Otherwise, isolation objective would not be achieved. On the other hand, the use of higher gain amplifiers compromises the distortion performance. The amplifiers also amplify signals to the level required by SH lasers, especially lasers with high input level requirements.

Table 5: Input/Output Specification for Sublevel 2

	Principal SH		Back-up SH		Local ON		Local Signals	
Parameter	Input	Output	Input	Output	Input	Output	Input	Output
Broadcast analog, level (broadcast digital 6-10 dB lower)	17±3 dBmV	15, 18, or 32 dBmV ±1.5 dB	17±3 dBmV	15, 18, or 32 dBmV ±1.5 dB	17±3 dBmV	20 to 31 dBmV	NA	NA
Levels from local programming sources	29 to 46 dBmV	16, 19, or 33 dBmV	31 to 48 dBmV	18, 21, or 35 dBmV	33 to 45 dBmV	23 to 35 dBmV	Max 59 dBmV	29 to 46 dBmV
CNR (min)	63 dB	60 dB	63 dB	60 dB	63 dB	60 dB	67 dB	63 dB
CTB (max.) for Options 1B and 2B with 32 dBmV lasers	NA	-86 dBc	NA	-75 dBc	NA	-86 dBc	NA	NA
CTB (max.) for the remaining options	NA	-86 dBc	NA	-86 dBc	NA	-86 dBc	NA	NA
CSO (max.) for Options 1B and 2B with 32 dBmV lasers	NA	-75 dBc	NA	-67 dBc	NA	-75 dBc	NA	NA
CSO (max.) for the remaining options	NA	-75 dBc	NA	-75 dBc	NA	-75 dBc	NA	NA
Flatness (at the SH laser TP)	NA	±0.5 dB, including slope	NA	±0.5 dB, including slope	NA	NA		
Ratio of wanted to unwanted signals between local signals in different links		min 55 dB, preferably >65 dB		min 55 dB, preferably >65 dB		min 55 dB, preferably >65 dB		
Spurious							-65 dBc	-65 dBc
Port-to-port isolation							20 dB	20 dB

Local Programming Combining Network

Single analog modulator output levels are nominally set to 56 dBmV. This setting allows for a frequency response alignment margin. The minimum input CNR from the modulators should be 67.0 dB. Spurs should be no greater than -65.0 dBc and the isolation minimum of 20.0 dB port to port. Other signal sources (for example digital TV signals for local distribution or I-Net) are set at lower levels as per the system design.

Sublevel 3 I/O Specifications

Input Splitting Network

Sublevel 2 output levels to Sublevel 3 inputs are predetermined by Sublevel 2 optical node pre-amplification network. The signals are then split to feed 32, 64, 96, or 128 optical nodes.

Optical Node Pre-Amplification Network

The signals from the input splitting network are pre-amplified by high quality power doubling amplifiers. The pre-amplifiers' main purpose is to provide adequate levels to the ON lasers. A single amplifier should feed a limited number of homes passed to limit failure groups. The analog outputs to the optical node lasers should be set at either 15, 18, or 32 dBmV with digital outputs set at the design relative levels.

TSD Signal Combining Network

Digital TSD levels to the 8-way combiner should be adjustable between 27 and 48 dBmV. This requires a 59 dBmV/6 MHz level capability from TSD transmitters. If this level is not available, lower input lasers must be deployed, TSD level must be lowered or transmitter splitting must be limited.

Table 6: Input/Output Specification for Sublevel 3

	Broadcast and Local Input Splitting Network		TSD Input Combining Network		Amplification Network	
Parameter	**Input**	**Output**	**Input**	**Output**	**Input**	**Output**
Level (broadcast and local analog, broadcast and local digital 6-10 dB lower)	20 to 31 dBmV	9 to 13 dBmV	NA	NA	9 to 13 dBmV	15, 18, or 32 dBmV
Levels from TSD sources			27 to 48 dBmV	6 to 27 dBmV		
CNR min	60 dB	60 dB	NA	NA	60 dB	56 dB
CTB max.	-86 dBc	-86 dBc	NA	NA	-86 dBc	-70 dBc (-86 dBc for 18 dBmV input lasers)
CSO max.	-75 dBc	-75 dBc	NA	NA	-75 dBc	-66 dBc (-75 dBc for 18 dBmV input lasers)
Flatness (at the SH laser TP)	NA	NA	NA	NA	±0.5 dB, including slope	±1.0 dB, including slope
Spurious			-55 dBc	-55 dBc		

Sublevel 4 I/O Specifications

Table 7: Input & Output Specification for Sublevel 4

	Forward		Reverse	
Parameter	**Input**	**Output**	**Input**	**Output**
Maximum level (average power/6 MHz)	59 dBmV	27 to 48 dBmV	20 to 32 dBmV	-5 to 10 dBmV

WIRING AND CABLING PRACTICES

All cables within the combining /splitting network should be routed between their attachment points the shortest possible way. All cable bends must be performed in sweeps with a radius >2.5" for individual cable jumpers and with a radius >5" for cable bundles for series 6 and 59 cables and for video cables. The cables in bundles must be neatly dressed. All cables must be secured to provide reliable support. In places exposed to damage (chafing, abrasion, compression, impact), the cables must be adequately protected by placing them in concealed channels or by covering them with adequately rated raceways. All RF and IF cables should be of quad-shield design and approved as headend cables. All baseband video cables must be of video type.

All unused ports of all combiners and splitters must be terminated.

SUMMARY

The described above combining /splitting network for headends and hubs is an example of the network design for a particular HFC network architecture. However, the concepts presented above are universal to many alternative HFC architectures addressing different market sizes and network configurations. The main concepts are:

- a modular design with separate modules for broadcsat signals, local programming signals, targeted service delivery signals, and reverse signals;
- setting clear objectives for each module and optimizing the module design to meet these objectives;
- clear specifications for module interface parameters for design compatibility.

The complexity of the modern HFC networks and the variety of service types (broadcsat, local, targeted) require a rigorous approach the headend and hub facility design, including their RF combining/splitting networks. The paper presents TCI's experience and choices with an attempt to make them as universal as possible.

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