ORNL/TM-10118

OAK RIDGE NATIONAL LABORATORY

MARTIN MARIETTA

Building Distribution System Design Criteria for the ORNL/Interplant Broadband Network

R. W. Hayes
T. W. Hayes
D. A. Clayton
J. M. Jansen Jr.

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
NTIS price codes—Printed Copy: A03; Microfiche A01

ORNL/TM-10118
Distribution Category
UC-37, Instruments

Instrumentation and Controls Division

BUILDING DISTRIBUTION SYSTEM DESIGN CRITERIA FOR THE ORNL/INTERPLANT BROADBAND NETWORK

R. W. Hayes
T. W. Hayes
D. A. Clayton
J. M. Jansen, Jr.

ORNL/TM--10118

DE89 001142

Manuscript Completed: February 28, 1986
Date Issued: December 1987

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-84OR21400

TABLE OF CONTENTS

ABSTRACT

This document sets forth the guidelines necessary for the design and implementation of building distributions and trunk extensions for the ORNL/interplant broadband network while maintaining the standards of quality required for reliable system performance. This document addresses the various aspects of hardware selection and design criteria as well as testing and documentation. These criteria have been used since February 1986 to extend the network to a dozen new buildings.

1. INTRODUCTION

Martin Marietta Energy Systems, Inc. is currently extending the ORNL/Interplant Broadband Network—a high-speed, bidirectional broadband coaxial cable distribution system—among the DOE facilities in Oak Ridge, Tennessee. The system is made up of readily available commercial CATV components. Broadband communication is based on two-way transmission of information (data and/or video) over a midsplit coaxial cable at a radio frequency (rf) of 5 to 108 MHz reverse and 174 to 300 MHz forward using frequency division multiplexing. All information is carried on one coaxial cable and is distributed to individual buildings over a main trunk system.

The main trunk consists of a branching tree network of high-quality cables, amplifiers, and directional couplers leading from the head end, which acts as the central broadcast and retransmission facility. Individual organizations tap onto this trunk system to distribute the cable network internally in their respective buildings. All cable users are totally dependent on the main trunk for transmission of information; it is therefore imperative that the quality of the trunk and of the distribution system be maintained at the highest possible level. Any compromise in the integrity of the trunk or the distribution system can seriously impair the effectiveness of the entire system.

It may seem that each building distribution network is isolated from the main trunk system by the presence of the distribution amplifier. This is not the case, however, because the amplifier passes signals in both directions. Improper termination of branch cables will result in standing rf waves and deterioration of the trunk system; therefore, building distribution systems must also exercise a high level of quality control in order to maintain the integrity of the trunk.

The purpose of this report is to provide requirements and guidelines to ensure proper design and timely implementation of building distribution systems and trunk extensions while maintaining the standards necessary for high-quality system performance.

Broadband technology is a rapidly growing field and is becoming more and more easily applied. However, since broadband does deal with rf signals, important details may easily be overlooked. Not only is there a problem of noise and signal degradation within the system, there also can be leakage of rf signals into the surrounding area. Certain FCC regulations (Part 76, Subpart K) must be followed to avoid such rf interference.

It is, therefore, the goal of this document to provide such guidelines as are necessary to permit the timely design and implementation of building distributions and trunk extensions while maintaining the standards of quality required for reliable system performance. This document will address the various aspects of hardware selection and design criteria as well as testing and documentation. No attempt will be made to cover fire codes or building regulations as these topics are addressed in other documents and are not necessary for system quality control.

2. HARDWARE COMPONENTS

All hardware components used in the implementation of building distribution systems and trunk extensions must conform to the specifications outlined in the following sections and must be approved by the ORNL Instrumentation and Controls Division. A parts list should be included in design documents for proper approval.

2.1 TRUNK CONNECTIONS

Distribution systems for individual buildings must be connected to the main trunk system by means of a trunk-quality directional coupler or splitter which was part of the initial trunk cable or trunk extension installation. This device extends trunk signals to the building distribution amplifier installed within the building. The main trunk system is installed with appropriate directional couplers at buildings having a potential need for connection to the broadband network. If a directional coupler was not included in the original installation, it may be possible to obtain an appropriate feeder or trunk extension from an adjacent building. The installation of additional directional couplers on an existing trunk is highly irregular and must be approved by the site network manager and coordinated through the ORNL Instrumentation and Controls Division. The proper size directional coupler will be installed for the specified signal level at the input of the building distribution amplifier (minimum 10 dBmV forward pilot level), taking into account cable losses between the directional coupler and the amplifier. The connection between the directional coupler and the building distribution amplifier is considered an extension of the trunk and therefore requires trunk-quality components.

2.2 AMPLIFIERS

Each building distribution system requires at least one amplifier, located within the building or in an adjacent building. The amplifier is connected to the main trunk through a directional coupler or splitter (see Sect. 2.1). An additional amplifier may be included if necessary (cascade maximum is two) from the main trunk. Distribution amplifiers may be trunk bridging, intermediate trunk bridging, or terminating trunk bridging, as required by the application. Scientific Atlanta Series 6560 amplifier components will be used on the ORNL/Interplant Broadband Network to ensure compatibility and to meet all network specifications. If distribution systems require more than one distribution amplifier, their design must be closely coordinated with the ORNL Instrumentation and Controls Division.

2.2.1 Trunk Bridging Amplifiers

A trunk bridging amplifier is a standard trunk-quality amplifier with added bridging capability. It may be inserted in the trunk wherever it is desired to continue the trunk as well as distribute signals to building feeders. This is accomplished by a directional coupler included in the amplifier to tap off signals from the main trunk line to drive the bridger amplifier, which in turn drives the feeder maker. The feeder maker consists of a two-, three-, or four-way power splitter to provide signal for up to four building feeders. In order to permit future expansion, four-way feeder makers will be used on the ORNL/Interplant Broadband Network, with all unused feeders terminated. Proper diplex filters, pads, and equalizers will be installed with the amplifier along with automatic gain or slope control as required.

Typical installations of trunk bridging amplifiers consist of four modules installed in a trunk housing: regulated power supply, forward trunk amplifier, bridging amplifier, and reverse trunk amplifier (See Fig. 1). Two types of reverse trunk amplifier modules are used, automatic slope control (ASC) and automatic gain control (AGC), placed alternately in amplifiers cascading from the head end.

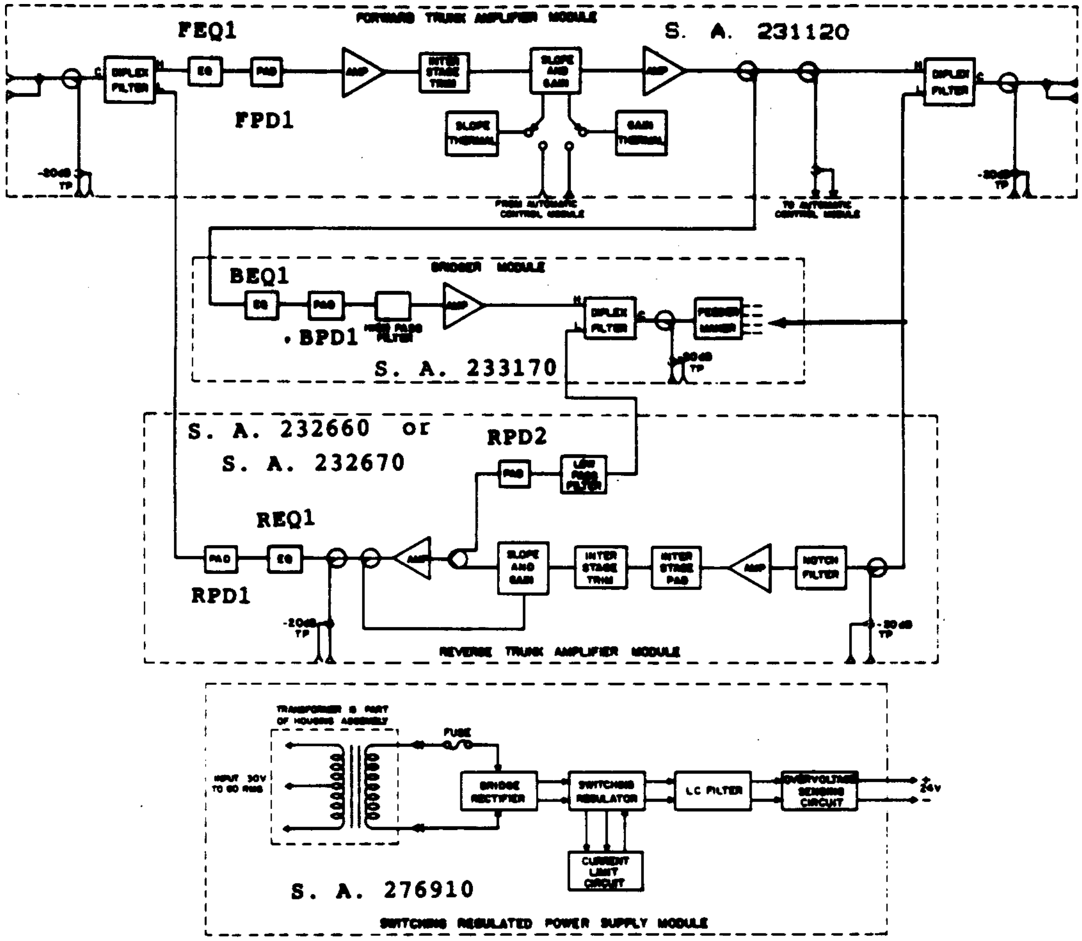
2.2.2 Intermediate Trunk Bridging Amplifiers

An intermediate trunk bridging amplifier is very similar to a trunk bridging amplifier except that there is no gain in the trunk circuit. Actually, there is an insertion loss associated with installation of an intermediate trunk bridging amplifier. This amplifier is used where building feeders are desired but the signal level on the trunk (greater than 24 dBmV forward pilot level) is such that no trunk amplification is required. Intermediate trunk amplifiers may not be used where the signal level of the forward pilot carriers is below 15 dBmV.

Modules required for this type of amplifier include regulated power supply, intermediate forward trunk amplifier, bridging amplifier, and reverse intermediate trunk amplifier (See Fig. 2).

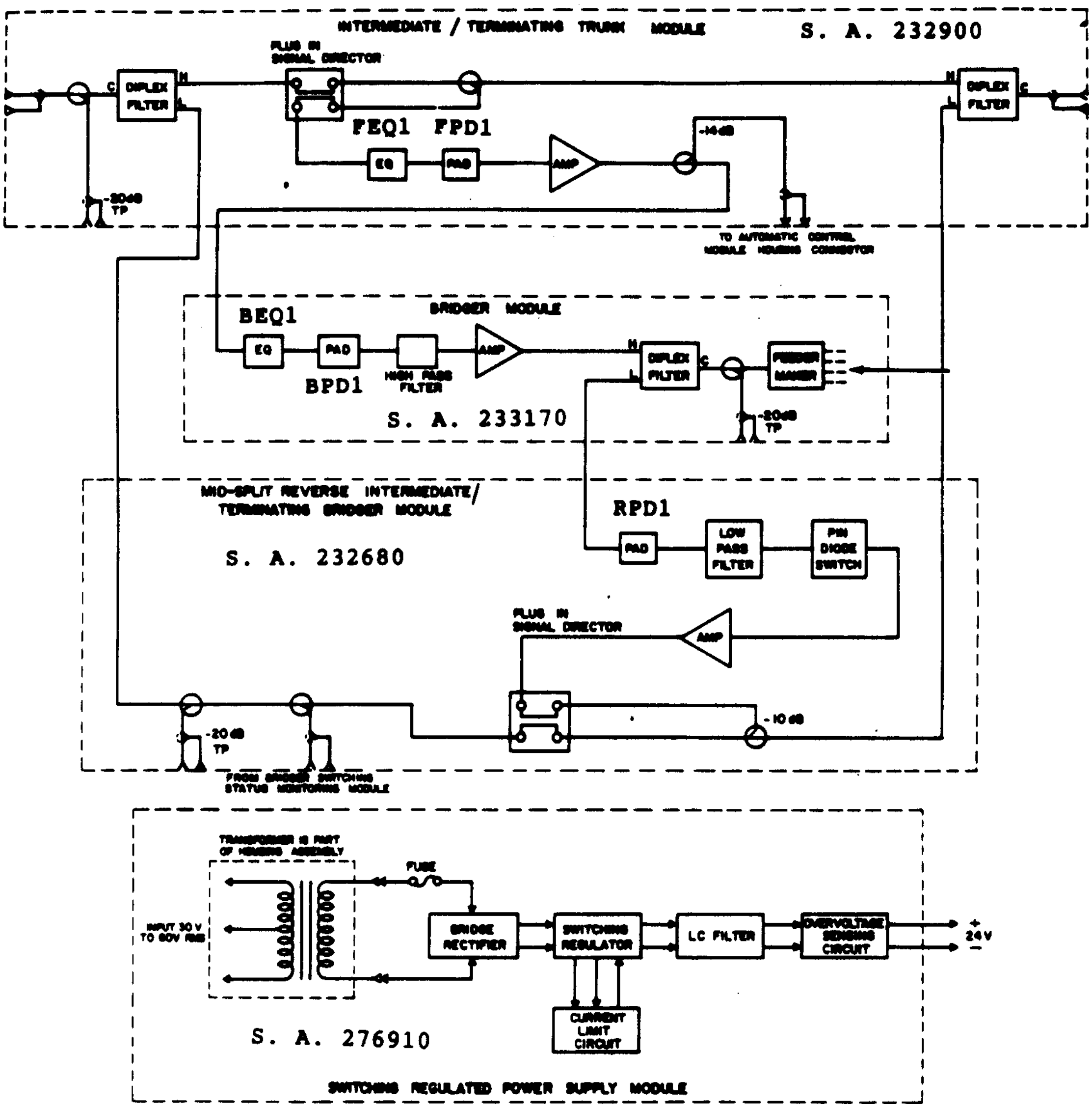
2.2.3 Terminating Trunk Bridging Amplifiers

A terminating trunk bridging amplifier is similar to an intermediate bridging amplifier except that the trunk is not passed through but terminated into 75-Ω termination (See Fig. 3). This amplifier is used where building feeders are desired at the trunk or trunk extension end. The same amplifier modules are used for the terminating trunk amplifier as for the intermediate trunk amplifier, except the module jumpers are set for termination. It should be noted that if AGC or ASC is desired upstream on the same branch as the terminating trunk bridging amplifier, a reverse pilot carrier generator must be included in place of a reverse trunk amplifier module. Also, a carrier blocking notch filter will be required at a junction of two branches of the trunk if both branches contain a reverse pilot carrier generator. Automatic



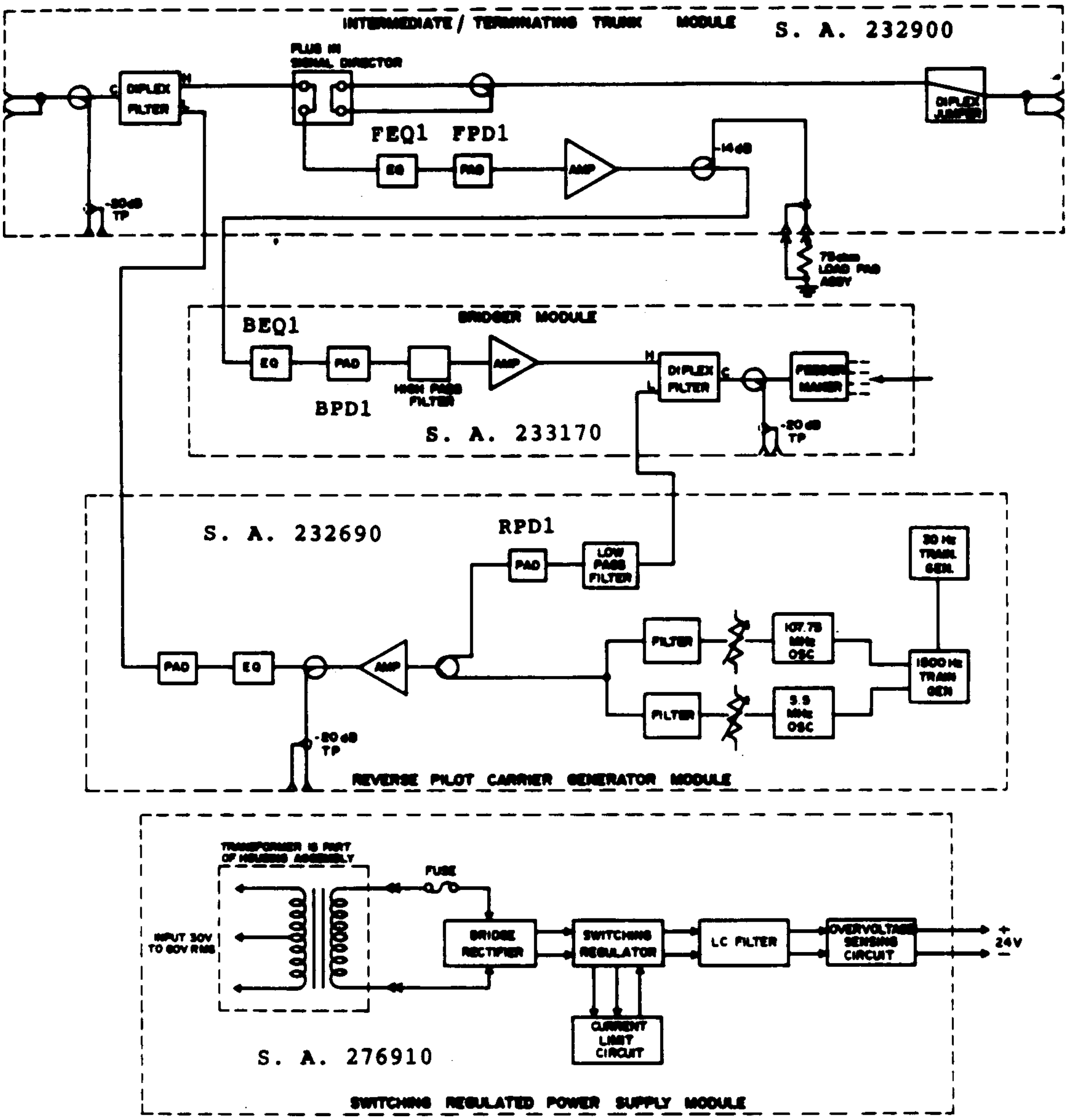
FEQ1 = cable loss @ 300 MHz
FPD1 = 22 dB - signal loss @ 300 MHz (including flat loss)
BEQ1 = 6 dB (typical)
BPD1 = 7 dB for 39-dB output at feeders
RPD1 = 19 dB - signal loss @ 108 MHz (including flat loss)
RPD2 = 1 dB (typical)
REQ1 = cable loss @ 108 MHz - 3 dB

Fig. 1. Trunk bridging amplifier.



FEQ1 - cable loss @ 300 MHz
FPD1 - 18 dB - signal loss @ 300 MHz (including flat loss)
BEQ1 - 6 dB (typical)
BPD1 - 7 dB for 39-dB output at feeders
RPD1 - 1 dB (typical)

Fig. 2. Intermediate trunk bridging amplifier.



FEQ1 = cable loss @ 300 MHz
FPD1 = 22 dB - signal loss @ 300 MHz (including flat loss)
BEQ1 = 6 dB (typical)
BPD1 = 7 dB for 39-dB output at feeders
RPD1 = 1 dB (typical)

Fig. 3. Terminating trunk bridging amplifier.

gain or slope control are not required when there are no more than two amplifiers in cascade from the main trunk system.

2.3 TAPS AND PASSIVES

Taps will be included at various locations along the feeder run as appropriate for installation of service connections. The building feeder is to be designed to run along hallways and through buildings for access from offices, computer rooms, and conference rooms. Power splitters will be installed when necessary to split the feeder cable signal into two or three branches. Line extender modules may not be used without special approval. Following is the minimum number of service connections required for functional areas.

Area	Taps required
Two-man office	1
Four-man office	2
Conference room (under 150 ft^2)	4
Conference room (over 150 ft^2)	8
16-bit computer area	4
32-bit computer area	8
Auditorium	8

2.4 CABLES

Following is a list of cables approved for use in designated areas (see Table 1 for design attenuation for each cable).

1. For aerial trunk runs, use jacketed cable supported by a suitable messenger (Scientific Atlanta GID-3 0.750-in. coaxial cable with copper-clad aluminum center conductor, S.A. Part No. 32-750J).

2. For direct burial runs, use heavy jacket flooded cable (Scientific Atlanta GID-3 0.750-in. coaxial cable with copper-clad aluminum center conductor, S.A. Part No. 32-750JHF, or Scientific Atlanta GID-3 0.5-in. coaxial cable with copper-clad aluminum center conductor, S.A. Part No. 32-500JHF).

3. For inside building distribution feeders, use Scientific Atlanta CableFlex 0.412- or 0.500-in. jacketed with copper-clad aluminum center conductor (S.A. Part No. 32-412CX for 0.412 in. and 32-500CX for 0.500 in.).

4. For drop cables from distribution taps to service outlets, use RG-59 type bonded coaxial cable with 95% aluminum braid coverage (Scientific Atlanta 5-1010).

Drop cables are installed from the tap output to the room where user equipment is to be connected. Drop cables will be a nominal length of 50 ft, dropped loosely into the room for flexibility of user equipment location. If wall-mounted service outlets are to be used, patch cable of a reasonable length will be placed in the room for equipment connection and its length subtracted from the length of the drop cable running from the tap to the service outlet. Excess cable between the tap and the outlet should be coiled and stored above the ceiling or at another convenient location.

Table 1. Cable attenuation

	Maximum attenuation (dB/100 ft @68°F)		
Cable type	5 MHz	175 MHz	300 MHz
GID-3 0.75 in.	0.10	0.68	0.91
CableFlex 0.500 in.	0.16	0.98	1.30
CableFlex 0.412 in.	0.20	1.20	1.59
Drop Cable RG-59	0.60	3.68	4.87

All cables except drop cables should be swept before and after installation to ensure that the jacket is not bent or kinked during shipping and installation. Cable should be swept after it is installed but before cutting and installing taps, splitters, or amplifiers.

2.5 CONNECTORS

Great care must be taken in preparation of the cable ends and installation of the connectors. Approved cable preparation and coring tools must be used. The following connectors are approved for use in building distributions:

1. Integral sleeve connector for 0.750-in. GID-3 cable, Gilbert GRS-750-CH-DU-01T.

2. Integral sleeve connector for 0.412 or 0.500-in. CableFlex, Gilbert GRS-412-CH-CX or GRS-500-CH-CX (for amplifier connections, suffix "-T" is required to denote extended pin length).

3. Type 'F' crimp ring connector for drop cables, Gilbert GF-59-AHS/290.

Since these connectors are relatively new to Energy Systems employees, electricians must be instructed on proper installation procedures by qualified personnel before any feeder cables are installed. Instruction will include a videotape of the correct procedures as well as hands-on practice.

2.6 POWER SUPPLIES

Power must be provided to all building amplifiers from within the building distribution system or from the main trunk system. Therefore, the specification and installation of power supplies must be coordinated with the site network manager and the technical manager to ensure the economical availability of power. Appropriate power blocks must be installed in the appropriate amplifiers to distribute power in a safe manner.

2.7 TERMINATIONS

All unused tap outputs, feeder outputs, and feeder and trunk cable ends must be properly terminated into an approved 75-Ω termination. Drop cables and service outlets must be terminated when not in use. Normally, drop cables will not be installed if there are no immediate plans to procure broadband equipment for a given location. This is necessary to reduce signal reflections from unterminated cable, which would introduce standing wave interference into the system.

3. DESIGN CRITERIA

3.1 NOISE INJECTION

Proper installation of all connectors and active and passive components and termination of all unused outputs will minimize noise injection. Only approved amplifier components may be used in order to ensure minimal noise injection, cross modulation, and composite triple beat. (Installation of cables, connectors, and other components is discussed in Sect. 2.)

3.2 RF EMISSIONS

In order to conform to FCC regulations, rf emissions must be kept below a specified ceiling. To conform to this specification, only approved components and installation procedures may be used. The installed system must be tested by the ORNL Instrumentation and Controls Division for conformity to regulations.

3.3 SIGNAL LEVELS AND TILT

The building distribution network should be designed to provide sufficient signal levels to the service outlets (10.0 dBmV minimum, 13.0 dBmV maximum) and maintain them for a proper signal-to-noise ratio. Also, for long feeders the amount of tilt due to the difference in frequency response of the cable to high and low frequencies must be calculated and compensated if necessary.

3.3.1 Trunk Signal Levels

The trunk signal level should be maintained at 10 to 32 dBmV for the forward pilot carriers and 15 to 35 dBmV for the reverse pilot carriers (where applicable). Amplifiers and pads should be installed to maintain these signal levels throughout the trunk cable run. The flatness of the trunk's reverse (5 to 108 MHz) and forward (174 to 300 MHz) bands should be maintained at better than 3 dB by use of automatic slope compensation in trunk amplifiers and by use of appropriate trim networks. Selection of trim networks must be coordinated with the ORNL Instrumentation and Controls Division.

3.3.2 Feeder Signal Levels

Building feeders should maintain a signal level high enough to provide the necessary service output level after installation of the taps and drop cables. Nominal output of the feeders from the bridging amplifier is 39 dBmV. Normally, tilt is not a problem in building feeders because the cable length is relatively short. However, if unusually long feeder runs (>250 ft) are necessary, tilt calculations should be performed to determine if any slope compensation is necessary.

3.3.3 Tap Output Signal Levels

In order to provide an adequate output signal level at the service outlet, the tap output must exceed the desired output level by the amount of loss in the drop cables. This should be calculated by taking the loss/ft of the specified drop cable at the highest frequency (300 MHz) and multiplying by the cable length.

Drop cable loss = loss/ft at 300 MHz × cable length
Tap output = drop cable loss + service output level

Note that the service output level is specified as a range. Therefore, the tap output specification is also a range of values. A range is necessary because the value of tap loss for available taps is in increments of 3 dB. Thus, the possible output values can be designed only in increments of 3 dBmV.

In order to provide proper signal levels in both the forward and reverse directions, all taps should come from a feeder emerging from a bridger module installed in a bridging amplifier. Only under special circumstances should the trunk be tapped directly for a service outlet, and it must be coordinated through the Instrumentation and Controls Division.

3.3.4 Service Output Signal Levels

In order to provide reasonable service to each area for present and future use, a minimum signal level of 10 dBmV is required at the user equipment connection (at the end of the drop cable). Since tap values are in steps of 3 dB, a range of 10 dBmV + 3.0 dB/-0.0 dB for the forward pilots is acceptable for the design. These levels should be measured at random locations on each feeder following installation to ensure proper signal levels for service connections.

4. DESIGN DOCUMENTS

4.1 NETWORK UTILIZATION PLAN

To ensure that design and installation of a building distribution system meet present and future needs, a broadband network use plan should be prepared and submitted for approval. This will also enable the network manager to maintain necessary channel allocations and monitor network loading and expansion requirements. The use plan should include the following items:

1. Building designation (which buildings are affected)
2. Name of building technical coordinator
3. Name of building administrative coordinator
4. Service requirements (current, in two years, and in five years)
5. Total number of terminal connections desired
6. Total number of personal computer connections (may be combined with the number of terminal connections if the split is unknown)
7. Number of local computer ports available for terminal connections
8. Number of RJE stations to be supported
9. Approval of the building technical coordinator and the building administrative coordinator
10. Approval of site network manager

4.2 DRAWINGS

Complete documentation for a building distribution system shall include at least one drawing (usually one drawing per floor) showing the location of all passive and active broadband devices. In order to provide timely and economical installation, existing floor plans may be used provided they are still accurate. Drawings shall be prepared as specified in this section and require the following signatures:

1. Building technical coordinator
2. Building administrative coordinator
3. Site network manager

The ORNL Instrumentation and Controls Division should be included in distribution of all design packages for the purpose of reviewing the design to ensure system compatibility and integrity. For the purpose of uniform definition and use of terminology, let us define an example as shown in Fig. 4. (Refer to Chap. 6 for a glossary of symbols and terms.)

The sample distribution system shown in Fig. 4 contains a bridging trunk amplifier with three 8-way distribution taps. This drawing contains enough details so that the system may be installed and maintained with little other documentation. To summarize, all drawings should include at least the following items:

1. Building floor plan

2. Location of the bridging trunk amplifier

3. Location of trunk and feeder cables

4. Location of all passive devices (distribution taps, splitters, and directional couplers)

5. The value of each passive device

6. The amount of cable between the passive devices

7. Which distribution tap is to serve each room

4.3 DESIGN CALCULATIONS

All design calculations shall be shown on a separate document indicating signal levels at the inputs and outputs of all active and passive components and at tap outputs. (If this information is included on the distribution system drawing, the drawing usually becomes too cluttered.)

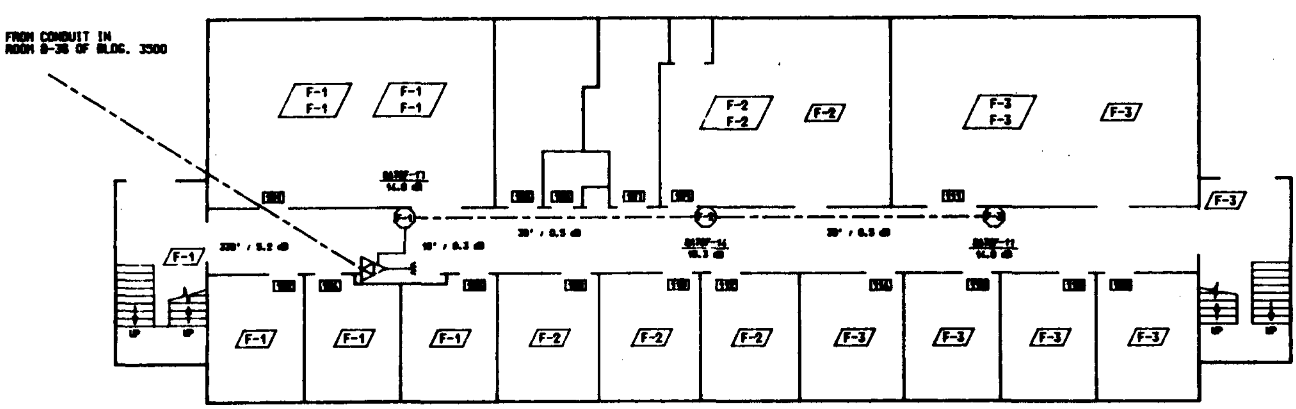


Fig. 4. Example drawing of building distribution system.

5. INSTALLATION AND ACCEPTANCE TESTING

Installation of building distribution systems will be performed by the appropriate organization. All cable preparation and installation tools must be approved by the ORNL Instrumentation and Controls Division. Cable sweep tests and other testing procedures also are to be approved before cable installation. All active components will be properly aligned according to specifications for the ORNL/Interplant Broadband Network. Following installation, acceptance testing will be performed (or witnessed if installation is performed by an outside contractor) by the ORNL Instrumentation and Controls Division before connection to the main trunk system.

6. GLOSSARY

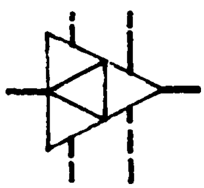
6.1 SYMBOLS

 - ROOM NUMBER

 - TAP NO. SERVING THE ROOM

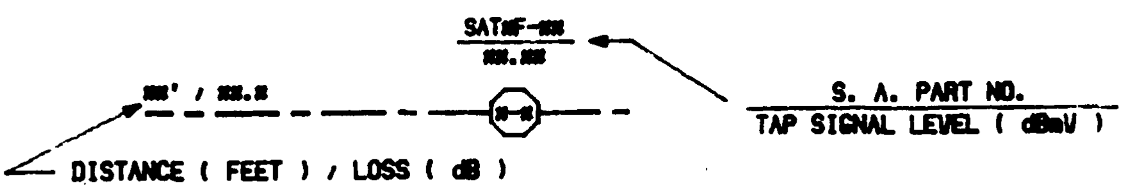
 - 0.412" CABLEFLEX

 - 8-WAY DISTRIBUTION TAP

 - BRIDGING TRUNK AMPLIFIER

 = FEEDER UP

 = 75 Ω FEEDER TERMINATOR



TYPICAL DISTRIBUTION TAP

6.2 TERMINOLOGY

1. Broadband - A local area network made up of industry standard CATV components.

2. CATV - Community antenna television

3. Head end - The location of the frequency translator. The head end for the ORNL/Interplant Broadband Network is located in Building 4500N, Room E206.

Amplifier - A modular subsystem used to increase the signal level throughout the network.

Distribution Tap - A device placed on building feeders that allows connection to user devices.

Directional coupler - A device used to divide a signal for transmission in two directions.

7. INDEX

ORNL/TM-10118
Distribution Category
UC-37, Instruments

INTERNAL DISTRIBUTION

1. D. L. Aslinger
2-5. D. A. Clayton
6. J. E. Cleaves
7. J. T. Cleveland
8. R. B. Conley, Jr.
9. J. L. Duncan
10. H. C. Ford
11. G. D. Inman
12-21. J. M. Jansen, Jr.
22. J. J. Jernigan
23. W. E. Knoch
24. K. G. Leihkauff
25. A. M. Lokey
26. D. R. Miller
27. J. A. Murray, Jr.
28. A. B. Ralph
29. J. A. Russell, Jr.
30. K. J. Scott
31. P. Singleton
32. C. A. Smith
33. H. F. Smith, Jr.
34. J. B. Smith
35. W. W. Smith
36. M. L. Stallo
37. B. A. Tye
38. J. B. Ball (Advisor)
39. M. J. Kopp (Advisor)
40. P. F. McCrea (Advisor)
41. H. M. Paynter (Advisor)
42-43. Lab Records Department
44. Laboratory Records ORNL-RC
45. ORNL Patent Section
46. I&C Division Publications Office

EXTERNAL DISTRIBUTION

47. Assistant Manager for Energy Research and Development, DOE-ORO, Oak Ridge TN 37831.
48-150. Given distribution under Category UC-37, Instruments.