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September 2, 1998

Mrs. Blanca S. Bayó
Director, Division of Records and Reporting
Florida Public Service Commission
2540 Shumard Oak Boulevard
Tallahassee, FL 32399-0850

Re: Docket No. 980696-TP

Dear Ms. Bayó:

Enclosed is an original and fifteen copies of BellSouth Telecommunications, Inc.'s Rebuttal Testimony of Dr. Randall S. Billingsley, Dr. Robert M. Bowman, D. Daonne Caldwell, G. David Cunningham, Dr. Kevin Duffy-Deno, Georgetown Consulting Group, Peter F. Martin and Dr. William E. Taylor, which we ask that you file in the captioned matter.

A copy of this letter is enclosed. Please mark it to indicate that the original was filed and return the copy to me. Copies have been served to the parties shown on the attached Certificate of Service.

Sincerely,

J. Phillip Carver

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cc: All parties of record
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ORIGINAL

REBUTTAL TESTIMONY OF DR. ROBERT M. BOWMAN
ON BEHALF OF BELLSOUTH TELECOMMUNICATIONS, INC.
BEFORE THE FLORIDA PUBLIC SERVICE COMMISSION
DOCKET NO. 980696-TP
SEPTEMBER 2, 1998

I. INTRODUCTION

Q. PLEASE STATE YOUR NAME, OCCUPATION, AND ADDRESS.

A. My name is Robert M. Bowman. I am an independent telecommunications consultant. My address is 10655 West Rowland Avenue, Littleton, Colorado, 80127.

Q. ARE YOU THE SAME DR. ROBERT M. BOWMAN WHO FILED DIRECT TESTIMONY ON AUGUST 3, 1998?

A. Yes. Attachment RMB-1 to my direct testimony, filed on August 3, 1998, provides a description of my experience and training relevant to this proceeding.

Q. WHAT IS THE PURPOSE OF YOUR REBUTTAL TESTIMONY?

A. I am testifying on behalf of BellSouth Telecommunications, Inc. (hereinafter "BellSouth"). My rebuttal testimony focuses on HAI 5.0a outside plant design from an engineering perspective.

Q. PLEASE SUMMARIZE YOUR REBUTTAL TESTIMONY.

I address two significant issues. First, many of the important assumptions within HAI 5.0a are not included in the user-adjustable inputs. Second, HAI 5.0a continues to violate engineering design rules for outside plant. This results in a network design that uses outdated technology and provides poor service quality. Consequently, HAI 5.01 fails to satisfy fundamental requirements of the Telecommunications Act of 1996 regarding access to advanced services and providing services to rural areas comparable to those provided in urban areas.

The local loop is a necessary component of local exchange service, and the costs of local loop plant are the largest part of the overall cost of supplying local exchange service. However, the HAI 5.0a provides a substandard telephone network and poor telephone service. The HAI 5.0a is clearly not a workable choice for Florida .

Q. HOW IS YOUR TESTIMONY ORGANIZED?

A. My testimony addresses two significant flaws in the HAI 5.0a's cost estimation processes:

- The HAI 5.0a user interface makes it difficult for the user to correct the unrealistic and outdated local loop engineering design.
- The HAI 5.0a uses certain outdated engineering parameters and assumptions to design the local loop.

II. HAI 5.0a ASSUMPTIONS THAT ARE NOT EASILY CHANGED

Q. MR. WOOD IMPLIES, E.G., AT PAGE 10 OF HIS DIRECT TESTIMONY, THAT HAI 5.0a IS EASY TO USE AND THAT THE MODEL INPUTS CAN BE READILY ALTERED. WOULD YOU PLEASE COMMENT?

A. Yes. Some of the important assumptions in HAI 5.0a are not user-adjustable. For example, HAI 5.0a does not place telephone poles as part of the aerial structure in the two highest density zones; in essence, it assumes that telephone poles are not required in this density zone. Furthermore, there is no user-adjustable input that allows the user to provide for the placement of poles as part of the aerial structure in the two highest density zones. The user would have to delve into the code to modify the Excel formulas to incorporate a more realistic assumption.

Q. IS THE EXCLUSION OF POLES IN THE HIGH DENSITY ZONES AN IMPORTANT OMISSION?

A. Yes. HAI 5.0a assumes as much as 60% to 85% of loop plant is aerial in its two highest density zones. However, the HAI 5.0a's documentation admits that the model never puts poles under its aerial cable for the two highest density areas. See the HM 5.0a, *Inputs Portfolio* (Revised: January 27, 1998), page 34. A note included there states that "HM 5.0a assumes Aerial Cable in the two most dense zones are Block and Building Cable, not support on poles."

The exclusion of poles in dense areas contradicts the direct testimony of one of HAI's leading proponents, Mr. Dean R. Fassett, provided on January 23, 1998 to the Wyoming Commission. Mr. Fassett has argued many times that it would not be reasonable to ignore the existence of poles in heavily concentrated areas, such as downtown areas, yet ignoring existing pole structures is precisely what the HAI 5.0a does. With no poles, there is no aerial structure cost per se, just the material cost of the cables. Eliminating pole costs results in an understatement of structure cost in the high-density zones, especially since HAI 5.0a assumes such a high percentage of aerial plant. Block cable is aerial cable attached to the sides of buildings. It is decades-old technology, the technology of a bygone era, and inappropriate to use in a modern telephone network. Owners typically do not permit unsightly attachments to the sides of their buildings, and like other forms of aerial structure, block cable is exposed to the weather, electric power and lightning.

Q. CAN YOU PROVIDE ANOTHER EXAMPLE OF AN HAI 5.0a ASSUMPTION THAT IS DIFFICULT FOR THE USER TO CHANGE?

A. Yes. HAI 5.0a does not include manholes, handholes, and pullboxes in the distribution plant. The Model does not have user-adjustable input tables that permit a user to easily add such items of structure to the distribution plant. For this reason, unless a user is capable of altering the Model's computer programming, the Model "automatically" substantially understates underground conduit costs in distribution plant.

HAI 5.0a assumes that distribution manholes, handholes, and pullboxes are not required. Thus, HAI 5.0a imposes this unrealistic assumption. In fact, the larger cable sizes needed in dense urban areas are often too big to sweep up from beneath the ground and attach to pedestals or poles on the surface. Manholes, handholes, and pullboxes are frequently required to build distribution plant in urban areas. Omitting them entirely from HAI 5.0a fails to recognize requisite costs incurred to serve urban subscribers.

Q. WHAT IS THE EFFECT OF HAI 5.0a NOT INCLUDING MANHOLES AND HANDHOLES IN DISTRIBUTION PLANT?

A. Omission of this distribution plant understates the costs actually incurred in providing basic local exchange service. Assuming handholes or pullboxes are spaced 600 feet apart, the HAI 5.0a understates the underground construction cost of distribution plant considerably. Furthermore, the HAI 5.0a does not have an input form allowing the user to incorporate manholes, handholes and pullboxes into the distribution design An explicit inclusion of these costs would require modifications to the model logic.

III. ENGINEERING DESIGN RULES

Q. DOES MR. WELLS DISCUSS STANDARD DESIGN PRACTICES IN HIS DIRECT TESTIMONY?

A. Yes. At pages 4 and 5, Mr. Wells suggests that HAI 5.0a relies on design assumptions that are similar to standard design practices. However, it appears that the HAI "Engineering Team" that Mr. Wells discusses in his direct testimony, has adopted guidelines that are inconsistent with industry standards.

Q. DOES HAI 5.0a ADEQUATELY REFLECT ENGINEERING DESIGN RULES WITH RESPECT TO ITS MODELING OF THE LOOP NETWORK?

A. No, it does not. HAI 5.0a does not adequately reflect engineering guidelines and practices published by Bellcore and AT&T, such as AT&T's "Outside Plant Engineering Handbook, August 1994," reprinted under the Lucent label in 1996. This reference is attached to my rebuttal testimony as RMB-1. Similar criteria are contained in the "Loop Technology Planning Guidelines" from Bellcore (BR 916-100-017).

HAI 5.0a violates these limits by extending copper loops beyond the digital loop carrier (DLC) remote terminal (RT) up to 18,000 feet without additional provisions, such as extended range channel units. Therefore, the local loop design in HAI 5.0a is not capable of providing adequate quality telephone service.

Q. WILL YOU ELABORATE ON WHY THE LOCAL LOOP DESIGN IN HAI 5.0a IS NOT CAPABLE OF PROVIDING ADEQUATE QUALITY TELEPHONE SERVICE?

A. Certainly. The line loss standard for good quality telephone service should not exceed 8.5 decibels (dB) of loss for the entire line, as specified in "Bellcore Notes on the Network", Issue 3, December 1997. HAI 5.0a places standard channel unit cards (plug-ins) in its Digital Loop Carrier (DLC). Each standard channel unit card inherently has 2 dB of loss. This permits a maximum of 6.5 dB of loss for the loop. Decibel loss, per 1,000 feet, for underground or buried cable at standard temperatures (i.e., 68 degrees) is 0.54 dB for 26 gauge cable and 0.44 dB for 24-gauge cable. Even with the conservative assumption that all cable is 24 gauge buried cable (aerial cable in the mix increases the loss), the dB loss for just the metallic loop on an 18,000 foot copper cable is approximately 8 dB. An additional 2 dB of loss inherent in the standard channel unit card brings the total dB loss to approximately 10 dB. Still further dB losses will occur if the line is aerial rather than buried or underground. Consider this additional loss to equal 0.5 dB, bringing the total loss to 10.5 dB. These calculations are shown in my attachment RMB-2.

Therefore, the HAI 5.0a 18,000 foot copper loop has approximately 2 dB more loss than the maximum loss allowed for good quality telephone service. Because dB is measured on a logarithmic scale, this additional loss is significant. Good quality telephone service as provided by the BCPM 3.1 network provides approximately 60% more power over the line that the HAI 5.0a 18,000 foot line provides. Customers would have to yell into the telephone of the HAI 5.0a network in order to be heard.

Q. WHAT ARE THE MAXIMUM LOOP LENGTHS THAT ALLOW GOOD QUALITY TELEPHONE SERVICE?

A. My attachment RMB-2 also shows the calculations of the maximum loop lengths of 11,100 feet (for 26 gauge cable) and 13,600 feet (for 24 gauge cable) that allow good quality telephone service. BCPM 3.1, in contrast to HAI 5.0a, reflects engineering standards by using larger 24 gauge cable beyond 11,100 feet and replacing standard channel unit cards with extended range line cards beyond 13,600 feet as described in the BCPM 3.1 Model Methodology.

Q. IS THERE A PROBLEM WITH HAI 5.0a'S USE OF THE STANDARD CHANNEL UNIT CARDS ON COPPER LOOPS THAT EXTEND TO 18,000 FEET BEYOND THE DLC?

A. Yes, there is a significant problem. The standard channel unit cards used by HAI 5.0a cannot reach copper loops that extend 18,000 feet from the DLC to the customer. In other words, HAI 5.0a models copper distances not supported by the technology assumed. HAI 5.0a and BCPM 3.1 both assume the use of the Litespan 2000 DLC technology (manufactured by DSC). DSC's documentation, however, states that the practical limit of the system is 1,000 ohms, and another vendor

(American Fiber Corporation, AFC) suggests that at maximum DC supervision, range transmission loss due to cable length may be greater than 8 dB. In another section of DSC's vendor documentation, it clearly states that the loop design for the standard channel unit card is based on Carrier Serving Areas rules, which, as pointed out above, limit loops to much shorter than 18,000 feet. Exhibit RMB-3 contains excerpts from the "DSC Practice Litespan Engineering and Planning" guidelines that describe limitations on loop lengths and the need for extended range line cards for loops beyond 12,000 feet. (See the "DSC Practice Litespan Engineering and Planning," OSP 363-205-010, Issue 6, July 1997, System Level Planning, Section 5.3 – CSA Transport Planning.)

Q. WHAT ENGINEERING PARAMETERS AND ASSUMPTIONS AFFECT HAI 5.0a'S LOCAL LOOP DESIGN?

A. The HAI 5.0a model connects the outlier clusters to the main cluster using outdated T1 copper. T1 carriers are digital technology permitting 24 channels over two copper pairs. Typically, engineering practice includes protection or redundancy for these systems by adding a second live copper pair available to continue a call should the first pair fail. The HAI 5.0a model includes no such protection, which violates good engineering practice.

Since HAI 5.0a only models one T1 carrier per outlier cluster, the Model does not have any additional capacity available for requirements such as ISDN, video, or graphics. For advanced services, the HAI 5.0a network would have to be overlaid with additional copper cable and repeaters, as well as DLC electronics. This would require digging trenches again, possibly in existing neighborhoods, which is not only expensive, but also very disruptive to existing homes and landscaping. The BCPM 3.1's choice of fiber DLC technology requires only that additional electronics be added at the DLC site.

Q. DOES HAI 5.0a MEET THE CRITERIA ESTABLISHED BY CONGRESS AND THE FCC REGARDING THE PROVISION OF ADVANCED SERVICES?

A. No, it does not. HAI 5.0a does not even meet the criteria for the provision of plain old telephone service (POTS) and modem/fax connections, as discussed above, much less criteria for other advanced services. In addition, HAI 5.0a attempts to identify the cheapest technology to use without any regard for the types of services offered now or in the future. HAI 5.0a purports to evaluate the costs of choosing fiber versus copper as a transport medium. If copper is the cheapest, HAI 5.0a selects it as the medium of choice.

Choosing copper over fiber generally hinders the provisioning of some business voice grade services such as PBX, WATS, etc., and further restricts modem/fax connectivity. Also, as I indicated earlier, customers may have to shout over the phone to be heard. PBX, and WATS may not work at all, depending on the loop length. Using HAI 5.0a for unbundled network elements exacerbates the problem because the LECs do not necessarily know how competitors will use the LECs' facilities. Additional costs would be incurred to provision copper cable for many of these services.

Two of the principles for universal service established in the Telecommunications Act of 1996 are relevant here. First, that: "access to advanced telecommunications and information services should be provided in all regions of the Nation." And second, that services in rural areas be comparable to those in urban areas. In addition, the FCC stated in their November 13, 1997, Public Notice (DA 97-2372) that the definition of supported services should "advance with technology."

HAI 5.0a does not satisfy the universal principles established by Congress and rather than advancing with technology, HAI 5.0a incorporates unrealistically long copper loops and 1960s technology with its choice of copper over fiber.

Q. HOW DOES BCPM INCORPORATE PROPER NETWORK DESIGN FOR GOOD QUALITY TELEPHONE SERVICE?

A. To overcome the difficulties of long loops, the BCPM standard design is to not exceed 12,000 feet of copper cable on any customers loop connected to a DLC unit. This is in contrast to the HAI 5.0a model, which designs customer loops connected to DLC units to 18,000 feet, and possibly beyond. The difficulties of long loops have been discussed above in this testimony.

In Florida, BCPM models only 4,169 lines over 12,000 feet from the DLC site. This is from a base of 9,842,000 million BellSouth lines, and represents only about 4/100 of one percent of the lines. In contrast, we estimate that the HAI5.0a models over 47,000 lines in excess of 12,000 feet in length from the DLC sites, more than 11 times as many long loops as BCPM models. This is a significant number of lines, indicating that such long loops are standard design for HAI5.0a. Service to these 47,000+ customers would be inferior in quality.

SUMMARY

Q. WHAT IS THE OVERALL EFFECT ON THE LOCAL LOOP COSTS OF THE HAI 5.0a?

A. The HAI 5.0a model installs the cheapest technology possible, regardless of the quality of service needed by subscribers now or for the next century. By engineering an outdated inferior local loop network, the HAI 5.0a model unrealistically lowers the local loop costs for the lowest density areas and for the longest loops

The HAI 5.0a does not build adequate plant. It does not even provide adequate plant for plain old telephone service ("POTS"). By building to a total loop length of 18,000 feet, the transmission loss exceeds the maximum loop loss of 8.5 dB for quality voice transmission. Beyond a DLC, the same degradation of all services results. In addition, WATS, PBX, and CENTREX services will not always work in HAI 5.0a's network, whether served from a wire center or a DLC.

The HAI 5.0a's developers have made it difficult for individual users to correct its flawed and erroneous cost parameters and assumptions.

Corrections to the many loop design deficiencies in the HAI 5.0a are difficult for the user to ferret out. Then, to correct the many understated costs such as the 18,000 feet loop and the missing poles or manholes, the user has to locate the complex computer code in the undocumented or missing user-input values in EXCEL. Important parameters and assumptions are not available to the user through the user-input forms that the HAI 5.0a provides. This makes it difficult to modify the HAI 5.0a to put in acceptable values or engineering design.

Q. WHAT ARE THE IMPLICATIONS OF HAI 5.0a'S ENGINEERING DESIGN FOR THE TELEPHONE NETWORK?

A. The HAI 5.0a's preferences for the cheapest technology suggest old-style, old-fashioned technology. The HAI 5.0a chooses copper of inappropriate length, rather than fiber, as the preferred transport medium, and it chooses aerial construction predominantly, rather than the preferred buried or underground construction. By modeling the network as copper cable at inappropriate distances with aerial construction, the HAI 5.0a selects technology of the 1950's and 1960's, not modern technology that supports modem and fax connections. The HAI 5.0a even neglects to add the equipment necessary for its long copper loops to provide ordinary voice-grade telephone service, much less for more sophisticated services.

Q. WHAT DO YOU CONCLUDE ABOUT THE HAI 5.0a?

A. The HAI 5.0a model significantly and systematically understates local loop plant costs. Furthermore, the HAI 5.0a's flaws and errors are deeply embedded in the computer code of the HAI 5.0a model and undocumented; therefore, corrections cannot be made easily.

HAI 5.0a's chains connecting outlier clusters to main clusters are constructed of outdated T1 copper cable. If all plant were being built today, T1 would not be the economic choice. Having only one T1 serve each 24 channels of voice in the HAI 5.0a chain provides no protection to insure that the system will continue to operate in case of a system failure. Industry standards necessitate an additional T1 carrier for protection.

In general, the industry considers advanced services as any use of the basic network for service other than voice communications, particularly analog modems for computer internet connections and FAX machines, as well as ISDN (Integrated Services Digital Network), ADSL

(Asynchronous Digital Subscriber Line), HDSL (Hybrid Digital Subscriber Line), and possibly others. The HAI 5.0a T1 copper technology has no capacity available for additional requirements for advanced services. With its fiber configuration, BCPM can support such services.

The HAI 5.0a network would have to be overlaid with additional copper and repeaters, as well as DLC electronics, to meet additional requirements. This is expensive and disruptive to existing customers.

Q. DOES THIS CONCLUDE YOUR TESTIMONY?

A. Yes, it does.

FPSC Docket 980696-TP
Rebuttal Exhibit RMB-1

OUTSIDE PLANT ENGINEERING HANDBOOK

August 1994

AT&T reserves the right to make changes to the product(s) described in this document in the interest of improving internal design, operational function, and/or reliability. AT&T does not assume any liability which may occur due to the use or application of the product(s) or circuit layout(s) described herein.

Developed by
AT&T Network Systems Customer Education & Training

FPSC Docket 980696-TP
Rebuttal Exhibit RMB-1

Section 13

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Section 13

DIGITAL LOOP CARRIER SYSTEMS

GENERAL

The increasing demand for an assortment of special services has made it necessary to condition the local loop network to support these services. It must be able to accommodate a wide range of transmission applications including voice, data, video, sensor control, and many others. Some of these services require high rates of transmission. Existing copper facilities can support some of the services. However, in many cases, expensive reconditioning of the cable plant will be necessary before service can be provided. The goal is to have the entire local loop network ultimately capable of supporting a transmission rate of 64 kb/sec. Nonloaded 26-gauge cable is capable of providing this bit rate within 12,000 feet (3657.6 m) of the serving central office. Digital subscriber carrier (pair gain) is necessary to meet that bit rate beyond 12,000 feet (3657.6 m).

Carrier Serving Area (CSA) Philosophy

The Carrier Serving Area (CSA) concept is to sectionalize the wire center area into discrete geographical areas beyond 12,000 feet (3657.6 m) of the central office. This sectionalization is done during the long-range outside plant planning (LROPP) process described in Section 2 of this handbook. Each CSA will ultimately be served via a remote terminal (RT) which houses the digital carrier equipment and divides the feeder from the distribution network. The boundaries of the CSA are based on resistance limits of 900 ohms for the distribution plant beyond the RT. These limits basically equate to 9,000 feet (2743.2 m) of 26-gauge cable and 12,000 feet (3657.6 m) of 19-, 22-, or 24-gauge cable including bridged tap. After the CSAs are established, when relief is required in a route and it is economical to deploy digital carrier, the RT sites can be activated. Digital carrier is also applicable to individual customer buildings or groups of buildings such as a campus environment, industrial areas, shopping centers, and condominium and apartment complexes.

dB Loss with 18,000 foot metallic cable

(the HM 5.0 Assumption)

26 gauge cable metallic loss @ 18,000 feet	9.7 dB
Inherent Loss in standard DLC channel unit cards (unadjusted)	2.0 dB
Total loss (unadjusted for aerial cable loss)	11.7 dB
Allowance for additional aerial cable and channel card unit loss* (7.7%)	0.5 dB
Total loss	12.2 dB

24 gauge cable metallic loss @ 18,000 feet	8.0 dB
Inherent loss in standard DLC channel unit cards (unadjusted)	2.0 dB
Total loss (unadjusted for aerial cable loss)	10.0 dB
Allowance for additional aerial cable and channel card unit loss* (7.7%)	0.5 dB
Total loss	10.5 dB

Loss Standard for Good Quality Telephone Service (GQTS)

(The BCPM 3.1 Approach)

GQTS cannot exceed a total loss of -	8.5 dB
Inherent Loss in standard DLC channel unit cards (unadjusted)	-2.0 dB
Allowance for additional aerial cable and channel card unit loss* (7.7%)	-0.5 dB
Maximum Allowed Metallic Loss for GQTS	6.0 dB

26 gauge cable metallic loss per kilofoot @ 68° F	0.54 dB
26 gauge cable maximum loop length for GQTS	11,100 feet
24 gauge cable metallic loss per kilofoot @ 68° F	0.44 dB
24 gauge cable maximum loop length for GQTS	13,600 feet

* Metallic cable loss increases with increasing temperature; aerial cable is exposed to the outside environment, where temperatures can exceed 68° F. Channel card unit loss varies ± 0.5 dB from average of 2.0 dB.

deployed as any other unrestricted channel unit. If the average is greater than 5, Worksheet PW-1 and the factor for 7 repeaters is used.

5.3 CSA Transport Planning

A Litespan RT will ordinarily be located to serve distribution areas that make up a carrier serving area (CSA). If POTS and locally switched ground-start circuits (PBX-CO trunks) services are to be served exclusively through the pair-gain cables and need not operate on parallel copper feeders, then loops beyond the RT site can be rolled over with care up to an 18,000 feet extended CSA. This assumes RUVG2 is used throughout to provide, in this case, extended CSA or community dial office (CDO) replacement (see Section 5.3.2). Because the Litespan RT can also act as a hub for transporting or consolidating older DLC systems (SLC-96, SLC-Series 5), it may be advantageous to locate the Litespan RT in a site that allows for extension of T1 spans to remote terminal sites beyond.

5.3.1 Loop Plant Design

In most cases, the copper pair narrowband (voice) cables between the RT and the customer premises will conform to the CSA concept. CSA design rules can be found in *Narrowband Services Application Guide*, OSP 363-205-110. These design rules call for nonloaded pairs (22-, 24-, or 26-gauge wire) with a maximum physical range of 12,000 feet (including bridged tap) or 750 ohms conductor loop resistance, whichever occurs first. In the case of 26-gauge wire, this equates to a maximum loop range of 5,000 feet. Any combination of two gauges is permitted. Today the CSA design rules ensure quality 2-wire voice transmission and the capability to support advanced digital services, including repeaterless digital data service (DDS), ISDN basic rate transmission (2B+D), high-bit-rate digital subscriber line (HDSL), and asymmetrical digital subscriber line (ADSL).

5.3.2 Extended CSA Design/CDO Replacement

There are applications of the Litespan system where it is necessary to serve customers more distant than 12,000 feet (beyond CSA rules) from the RT. Economy often requires a 33% increase in length in nonloaded CSA loops, including bridge taps. Litespan's extended CSA is 12,000 ft using 26-gauge wire and 16,000 ft using heavier gauge wire. CDO replacements mean loaded and longer cable pairs are possible. While the Litespan -48 VDC channel units are capable of supervising a 1500-ohm maximum loop resistance line, all loops over 18,000 feet should be loaded, using standard H88 loading rules. The insertion loss at 1 kHz for extended CSA/CDO length loops exceeds common practice and approaches 10 dB, including a 2-dB loss in the Litespan RPOTS channel unit. It is strongly recommended, therefore, that RUVG2 or REUVG channel units be used in any Litespan RT that may be serving any loops longer than 750 ohms. With the REUVG channel unit, loops may be extended even farther with better 1-kHz loss. Also, there is matched precision balance and equalization automatically for high-frequency (3 kHz) rolloff, allowing nonloaded designs to 18,000 ft and loaded designs from 18,000 to 42,000 ft.

The RANI channel unit, available with Release 7.1, offers some of the RUVG2 capabilities and is an alternative to RPOTS without the 2-db loss restriction. Refer to the *Narrowband Services Application Guide*, OSP 363-205-110, for more information.

5.4 DSX-1 and T1 Span Extensions

A Litespan system is capable of delivering DS1 (1.544 Mb/s) services directly from the channel bank via the DS1U, ADS1U, T1U, and AT1U channel units. DS1-rate channel units may be located at the COT or RT and use the same physical slots as the narrowband channel units. In planning for the extension of DS1-rate facilities, certain design guidelines must be observed. These guidelines are familiar to engineers who have designed optical multiplexers and digital loop carrier systems into the telephone network.