

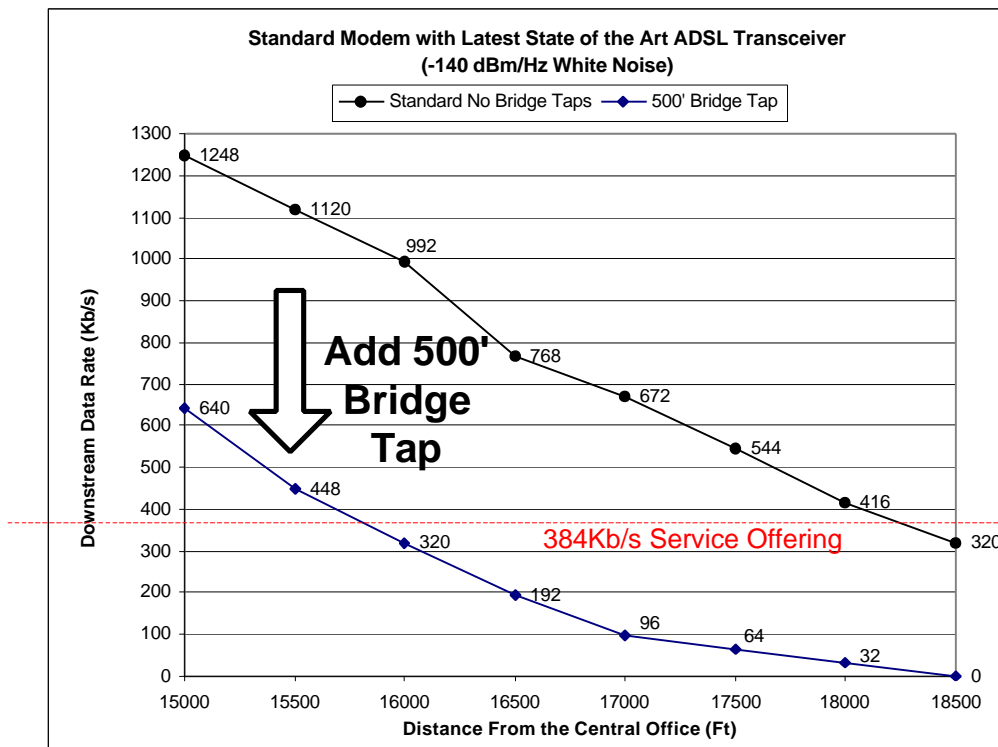
# Westell's New Multi-Hybrid ADSL Modem With Upstream PSD Shaping

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\* Section Recently Updated/Added

## Introduction

Bridged taps in the network and in-home wiring with or without micro-data filters look like non-terminated copper pairs to the ADSL frequency range. These non-terminated copper pairs can drastically change the impedance of the transmission line as seen from the modem. This impedance variation causes reflections of the upstream spectrum at the modem that can adversely affect downstream signal recovery, resulting in lower downstream data rates and margins.

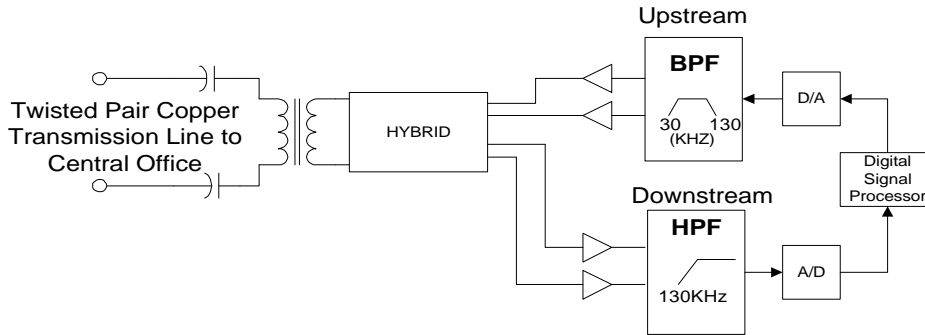


A 1997 Subscriber Loop Characteristics Study from Bellcore based on a survey of loops from a major Regional Bell Operating Company located in the Midwest has shown that bridge taps are quite prevalent. Approximately 75% of all loops have some type of bridged tap and approximately 33% of all loops have bridge taps between 250 and 500 feet. Note that this bridged tap length coincides with the “sour spot” for negative performance on ADSL transmission. Note that this statistic does not even include bridged tap affects related to in home wiring.

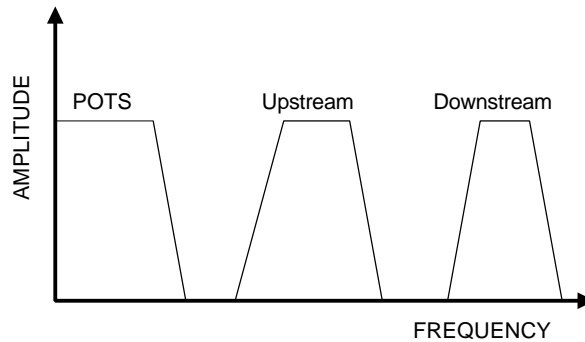
Bridged taps can severely impair ADSL performance and therefore is a limiting factor in loop range. Westell’s Multi-Hybrid modem uses multiple hybrid technology with upstream power spectral density shaping (PSD shaping) to help cancel the bridged tap affects. Significant performance increases can be realized with this technology under bridge tap and in home wiring conditions. The Multi-Hybrid modem will generally not increase performance on standard loops without bridge taps or on loops with bridged taps located >1000’ from modem.

## Hybrid Introduction

A hybrid is used in ADSL to separate transmit and receive signals on a 2 wire transmission line.



For an ADSL remote unit, the transmit and receive signals are Frequency Division Multiplexed in addition to having a hybrid. The figure below illustrates the frequency separation involved in an ADSL system. The transmit signal is from the remote unit to the central office (Upstream Data). The Receive signal is from the central office to the remote (Downstream Data).



The upstream occupies the bandwidth from about 30KHz to 138KHz. The downstream occupies the bandwidth from 170KHz and up. Note that only 32KHz separate the upstream and downstream frequency ranges. The transition area between the upstream and downstream bandwidths is where the hybrid is most necessary. High upstream signal power in the 138KHz range could be reflected back through a poor hybrid match of the transmission line into the downstream path and could interfere with downstream signal recovery.

## In-Home Wiring Issues

Early Days of ADSL Deployment used Plain Old Telephone (POT) Splitters:

In the early deployment days of ADSL CPE equipment, a POT splitter was used at the demarcation point in the Network Interface Device (NID) (refer to Figure 1 below). The NID is a box that is typically attached to the outside of the house that represents the demarcation point between telephone network owned equipment/wiring and customer owned equipment/wiring. The POT splitter approach was a very good method to prevent in-home wiring from adversely affecting ADSL performance. The POT splitter contained a low pass filter that separated the in-home wiring from the ADSL loop. The input to the low pass filter from the network side looked like a very high impedance to the ADSL frequency range and looked like a very low impedance to the standard POTS voice frequency range. This high impedance to the ADSL frequency range prevents in-home wiring problems from adversely affecting ADSL performance. Even if the customer wiring had a direct short across the pair, the ADSL modem would still perform just as well as it did before the short!

The drawback to this approach was that it could not be easily self-installed by the customer. The Telephone Company offering the service would need to send a person out to install the POT splitter and then an extra pair of wires would need to be run from the POT splitter to the modem. This was very inconvenient and costly.

**Figure 1 - ADSL with POT Splitter**

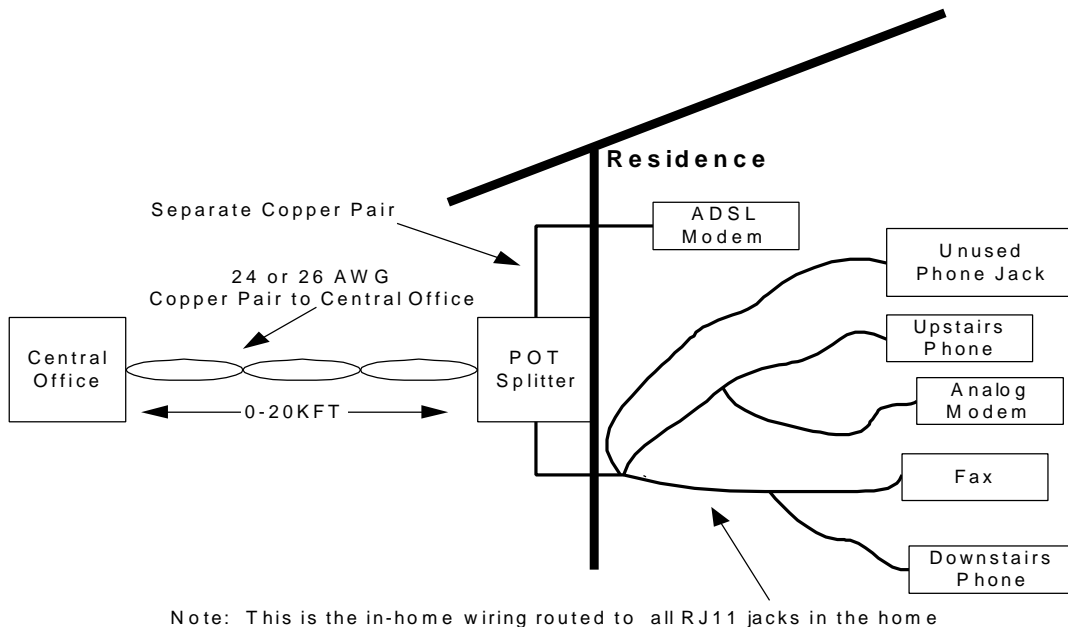


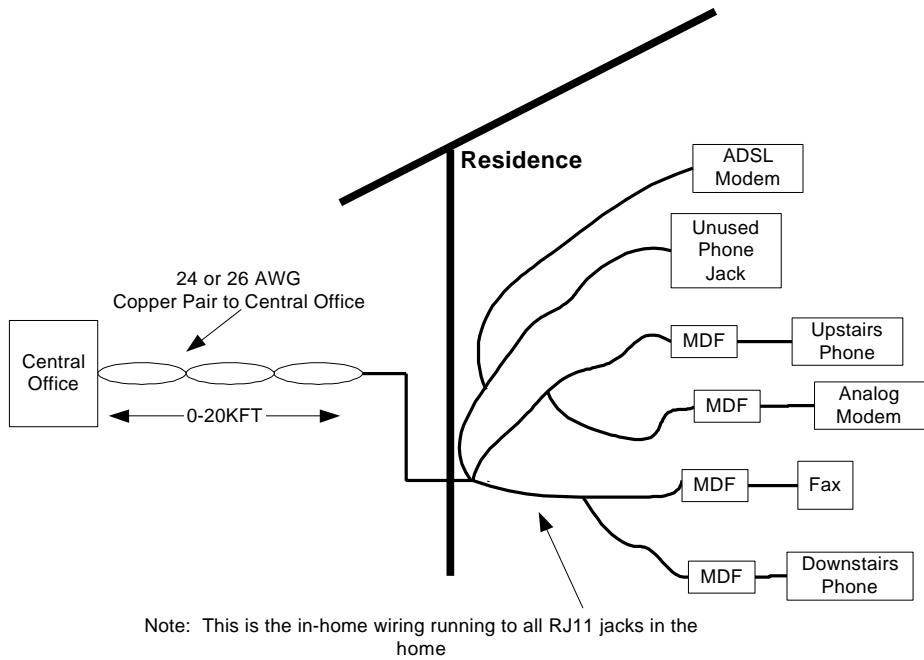
Figure 2 below represents the standard deployment topology of ADSL today. The ADSL service provider ships a self-install kit to the customer. This kit contains an ADSL modem and multiple Micro-Data Filters (MDF). The customer is instructed to install a MDF in-line with every phone jack in the house that is used by a POT type of device (phone, fax, analog modem, etc). The customer is instructed to connect the modem directly to a phone jack without an in-line MDF.

The MDF is simply a low pass filter that filters out ADSL Frequencies to POT devices and helps prevent POT broadband signaling transients from affecting ADSL performance.

POT type of transient conditions include ring application/removal, dial pulse, ring trip (picking the phone up during a ring), etc.

The MDF looks like high impedance to ADSL frequencies just like the POT splitter does. Note that MDF is at the end of each in-home wiring run. All this in-home wiring is now connected directly in parallel with the ADSL modem and can have an adverse affect on performance. This wiring looks very similar to a bridge tap.

**Figure 2 - ADSL Self-Install with Micro-Data Filters**  
**Why Bridge Taps and In-Home Wiring Adversely affect ADSL**



## ADSL Performance

A hybrid is used in ADSL to separate transmit and receive signals on a 2 wire transmission line. The key component of the hybrid is an impedance match circuit that is designed to mimic the input impedance of the transmission line over the frequency range of interest. If the impedance of the transmission line is exactly equal to the impedance of the matching circuit, then the transmit signal will cancel out completely from the receive signal yielding the best ADSL performance.

A typical ADSL Hybrid is designed to properly match the input impedance of cable without bridged taps. This impedance is rather well behaved over different lengths of cable.

**Table 1 - Input Impedance of 26AWG cable (far end ATU-C termination = 100 ohms)**

(Magnitude of Impedance shown in ohms)

<b>Frequency</b>	<b>10KFT</b>	<b>15KFT</b>	<b>20KFT</b>
100KHz	128	128	128
150KHz	122	122	122
200KHz	119	119	119
250KHz	118	118	118
300KHz	119	119	119

Note that the cable-input impedance is near 120 ohms from 100KHz through 300KHz and is very stable over various cable lengths. Standard ADSL hybrids are tuned to match this impedance criteria. The important matching frequency range of an ADSL hybrid is in the transition frequency range between the upstream and downstream spectrum. This is from about 100KHz to 250KHz

Table 2A, 2B, 2C shows 16KFT of cable input impedance before and after adding a 300FT, 400FT, 500FT-bridged tap at the modem.

**Table 2A - Magnitude of Input Impedance, 16KFT of 26AWG Cable**

<b>Frequency</b>	<b>-Before-</b>	<b>Add</b>	<b>-After-</b>
100KHz	128	<b>300'</b>	107
150KHz	122	<b>Bridge Tap</b>	93
200KHz	119	<b>⊥</b>	80
250KHz	118	<b>At Modem</b>	67

**Table 2B - Magnitude of Input Impedance, 16KFT of 26AWG Cable**

Frequency	-Before-	Add	-After-
100KHz	128	400'	98
150KHz	122	Bridge Tap	80
200KHz	119	⊥	61
250KHz	118	At Modem	43

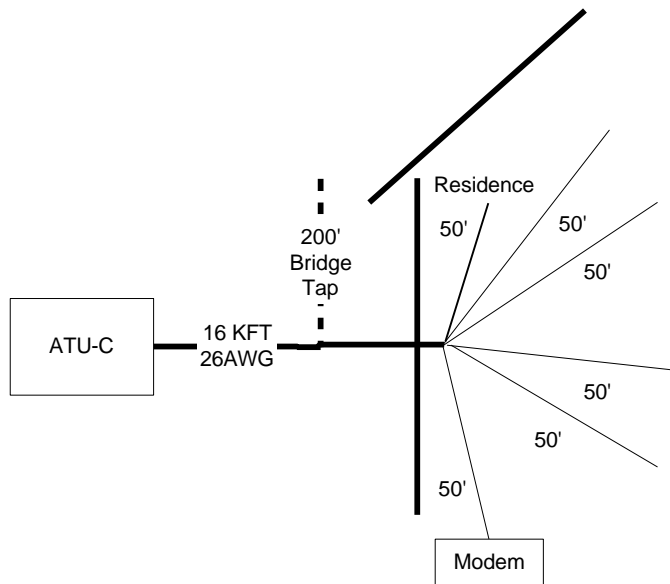
**Table 2C - Magnitude of Input Impedance, 16KFT of 26AWG Cable**

Frequency	-Before-	Add	-After-
100KHz	128	500'	88
150KHz	122	Bridge Tap	65
200KHz	119	⊥	43
250KHz	118	At Modem	25

Notice that with a bridge tap the impedance of the modem changes drastically over the frequency range. Designing a hybrid that better matches this condition increases performance.

### Input Impedance Change with In-Home Wiring

In-home wiring adds to the bridged tap affect. Suppose we have a house wired as shown below. The home has 6 phone jacks. Assume a star formation as shown below running to the RJ11 jacks in the home. Table 3 shows the impedance affects of this topology



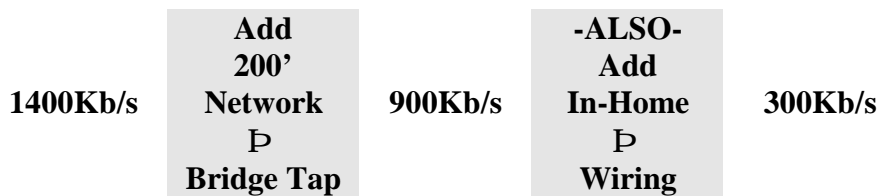
**Table 3 - Magnitude of Input Impedance, 16KFT of 26AWG Cable**

Frequency	Z1	Add In-Home Wiring Ⓟ Star	Z2	-ALSO- Add 200' Network Ⓟ Bridge Tap	Z3
100KHz	128		109		94
150KHz	122		97		77
200KHz	119		86		63
250KHz	118		77		50
<b>Down Rate</b> Ⓟ	<b>1400Kb/s</b>		<b>600Kb/s</b>		<b>300Kb/s</b>

Notice that this in home wiring star formation has very similar input impedance as a 300' bridged tap (Compare column Z2 to Table 2A). This corresponds to a decrease in data rate from 1.4Mb/s to 600Kb/s. A 57% decrease in performance!

Note that when a 200' Network bridged tap is added in addition to the in-home wiring, the total impedance closely matches the affects of a 400' bridged tap (Compare Column Z3 to Table 2B). The in-home wiring effectively added 200' to the network bridged tap. Another way to look at it is this:

**Table 4 - Downstream Data Rate at 16KFT of 26AWG Cable**



## Multi-Hybrid Modem

The Westell Multi-Hybrid Modem has 4 hybrid circuits that have been designed to match the impedance of various in-home wiring topologies and bridged tap conditions. The Multi-Hybrid Modem also contains upstream power spectral density shaping to further enhance the downstream performance. Note that this is a single ended modem solution for bridge tap and in-home wiring impairments. This technology works with standard ADSL DSLAMS deployed today.

While the multi-hybrid technology can significantly improve performance under bridged tap conditions, it cannot completely cancel out the adverse affects of bridged taps. The reason is that bridged taps also can cause impedance nulls in the middle of the downstream spectrum where the hybrid circuitry is not effective. These nulls in affect limit the amount of bits per carrier that can be transferred at that null. An impedance null can take the cable impedance from 100 ohms all the way down to under 20 ohms.

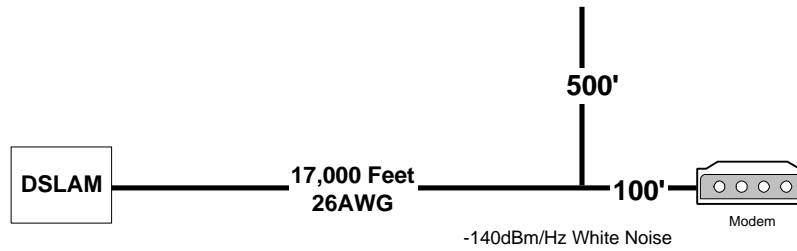
### **The 4 hybrids optimize performance on the following loop topologies:**

- **Hybrid #1** - Standard Hybrid: Straight Cable without bridged taps
- **Hybrid #2** - 0-1000' Bridged taps or in home wiring tap located 0 to 50' from modem
- **Hybrid #3** - 0-1000' Bridged taps or in home wiring tap located 250'-1000' from modem
- **Hybrid #4** - 0-1000' Bridged taps or in home wiring located 50'-250' from modem

During the training cycle, signal to noise measurements are quickly performed on each hybrid to determine the optimum hybrid for the loop conditions. Within a fraction of a second the best hybrid is chosen.

## PSD Shaping Technology

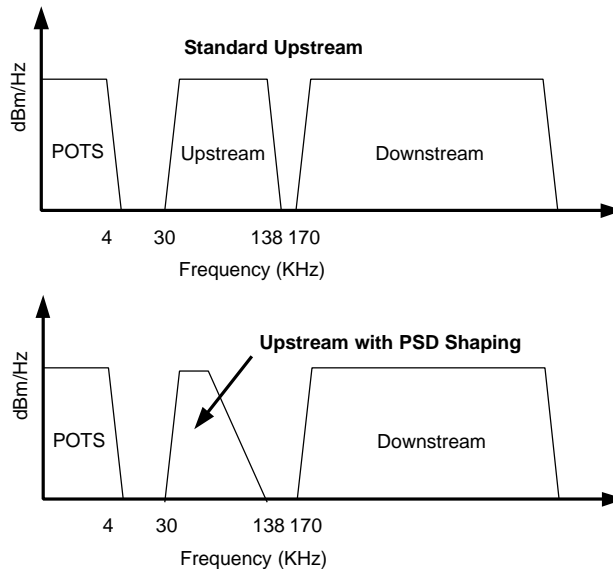
It is not uncommon for the upstream data rate to exceed the downstream rate under adverse bridged tap conditions. For example:

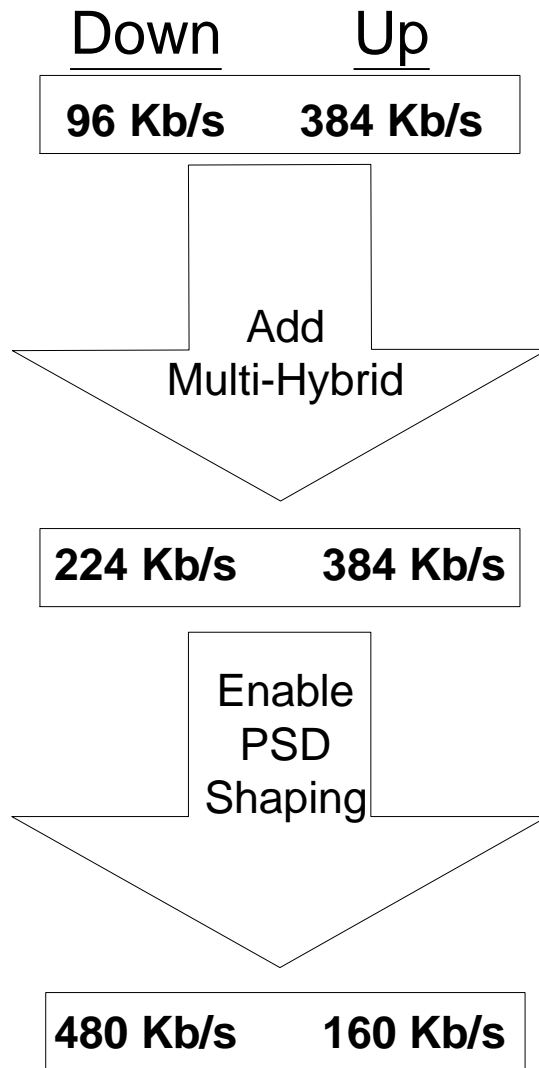
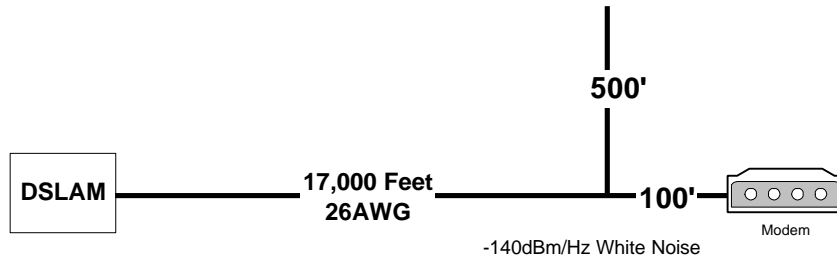


Standard Modem
Downstream Data Rate = 96 Kb/s
Upstream Data Rate = 384 Kb/s

It is typically desired for the Upstream to be 1/8 the Downstream data rate for a good web surfing experience. This example shows the upstream to be 4x the downstream rate!

In this type of condition, PSD shaping is desired. PSD shaping attenuates the upstream spectrum in the transition band which minimizes impedance mismatch reflections caused by bridge taps and in home wiring conditions.





The normal upstream signal of the modem is within the Power Spectral Density (PSD) limit of -40dBm/Hz. If the modem encounters a loop condition that severely degrades the downstream data rate without much effect on the upstream rate, then upstream PSD shaping will be turned on. This will roll off the upstream signal near the transition band between the upstream and downstream spectrums. This will cause the Upstream PSD to be even lower than -40dBm/Hz. This in affect assists the Multi-Hybrid modem by attenuating near end reflections in the transition band. Depending upon the loop noise condition, this often results in a data rate increase to the downstream signal with a corresponding decrease in the upstream data rate.

PSD shaping is currently implemented as 2 low pass filters. One filter is the standard upstream filter used in ADSL. The other filter has the 3dB low pass filter pole moved lower in the upstream spectrum. Future designs will have more than 2 filters to accommodate various degrees of PSD shaping.

The current implementation looks at the downstream data rate and line attenuation to determine when PSD shaping should be enabled. These two parameters can be factory set to whatever the customer wants. 384Kb/s downstream data rate with 60dB-line attenuation could be one possible default. With this setting, if the downstream data rate falls below 384Kb/s and the downstream line attenuation is greater than 60dB, then PSD shaping will be enabled.

If enabling the PSD shaping option causes the upstream data rate to fall below a pre-determined threshold, the software will automatically disable PSD shaping. The current upstream threshold is set at 128Kb/s. this parameter can be set to whatever the customer wants. It can also be easily increased to support future VOIP type services.

# Westell Multi-Hybrid Modem Performance Results

## Westell's B90-220025-04 Wirespeed Multi-Hybrid Modem and Westell's B90-210015-04 Wirespeed Dual Connect Modem vs Competition

The following data contained in this document shows the performance of the modems listed above over various line conditions containing a variety of bridged taps. Each bridged tap condition is described in the appropriate figure and uses either simulated or real cable.

The graphs represent downstream rates only. The charts below each graph show both the down and upstream rates for each data point taken. The test equipment and setup used for each loop condition is listed below.

### Central Office DSLAM:

Alcatel Mini-Ram

- Fast Mode
- 6dB Target Margin
- Rate Adaptive

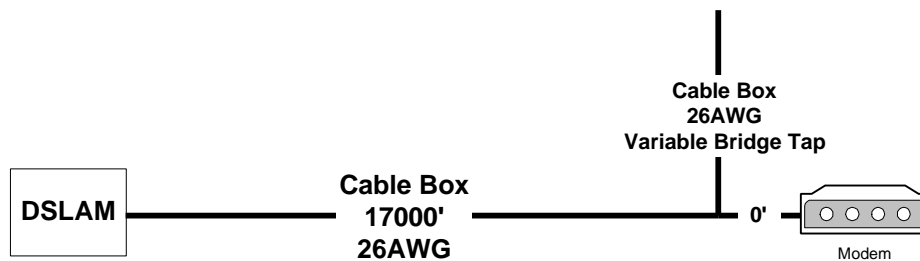
### Cable Box Line Simulator and Noise Generator:

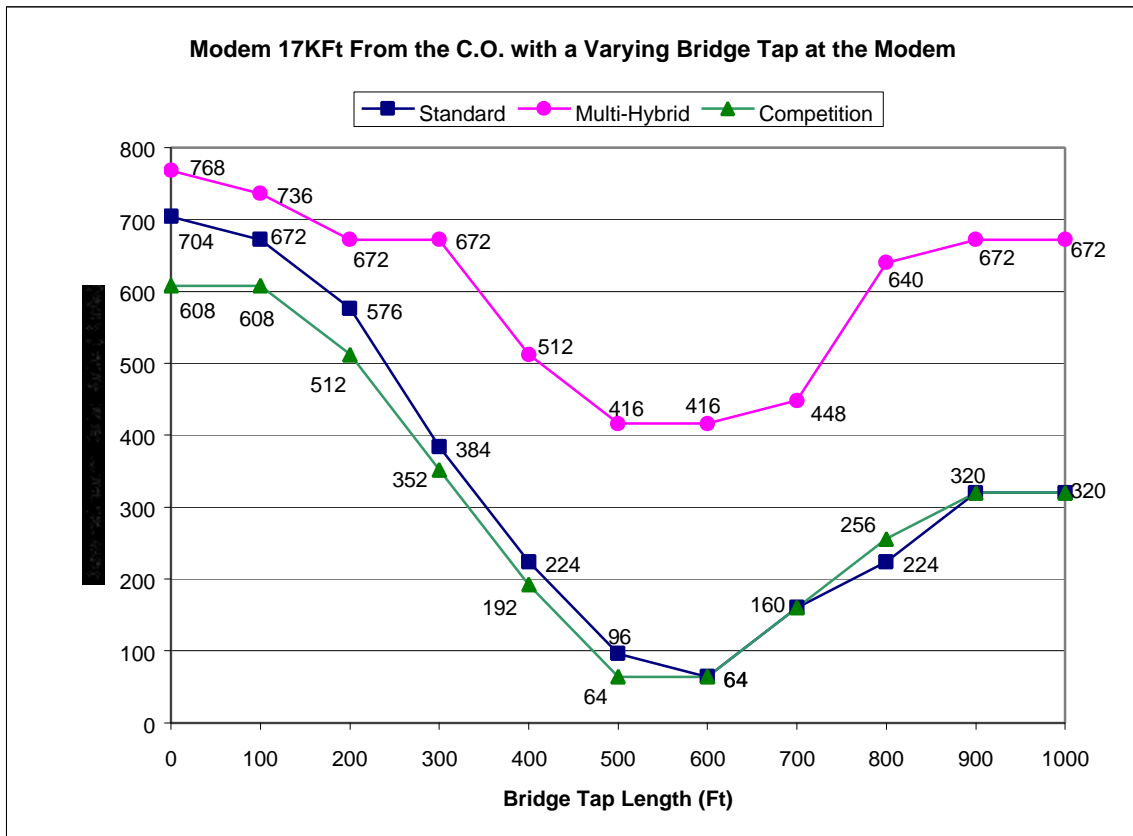
Spirent DLS400

- 140dBm/Hz White Noise applied at both the ATU-C and ATU-R

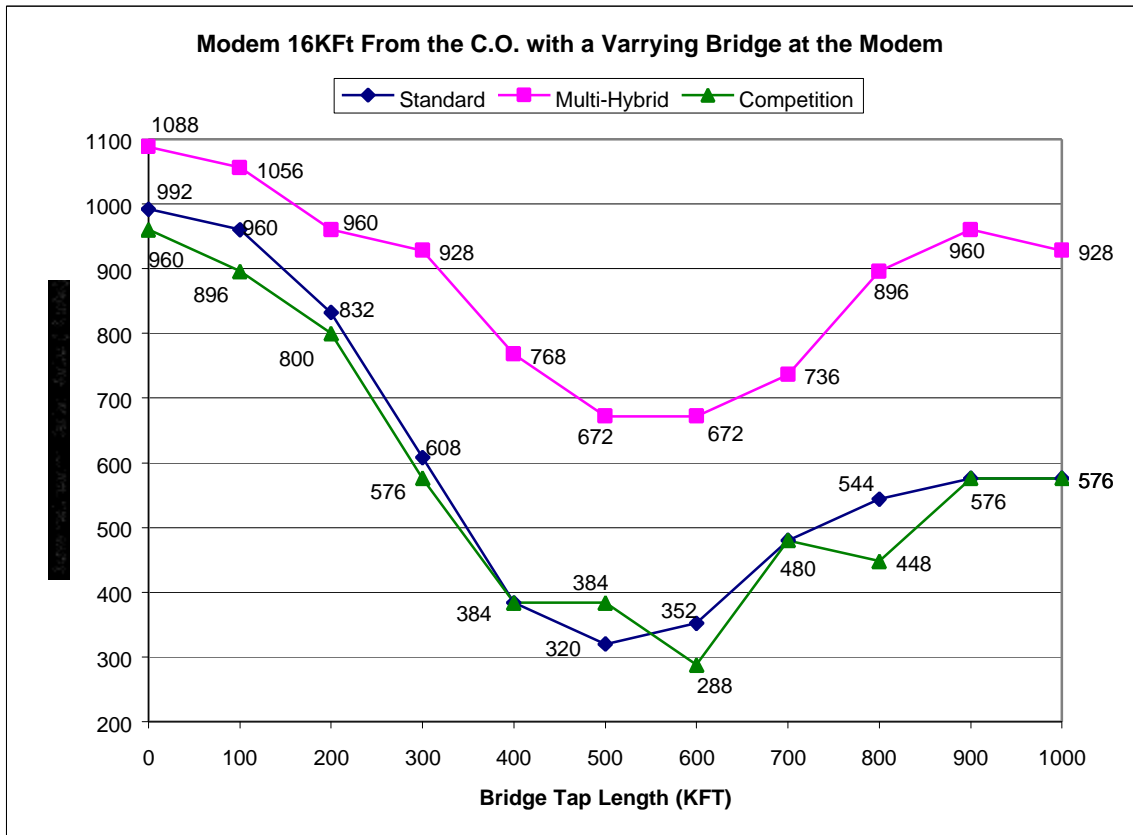
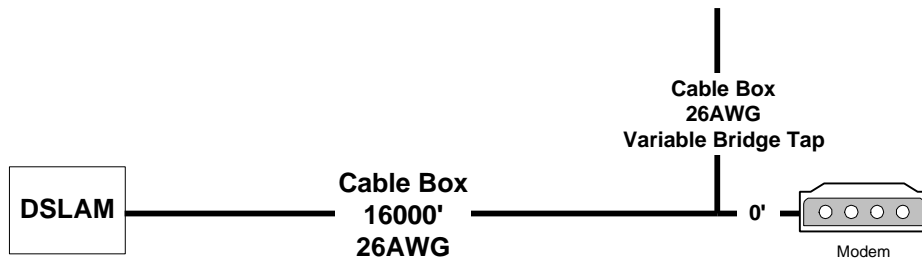
### External Bridged Taps:

AT&T real cable 2/26

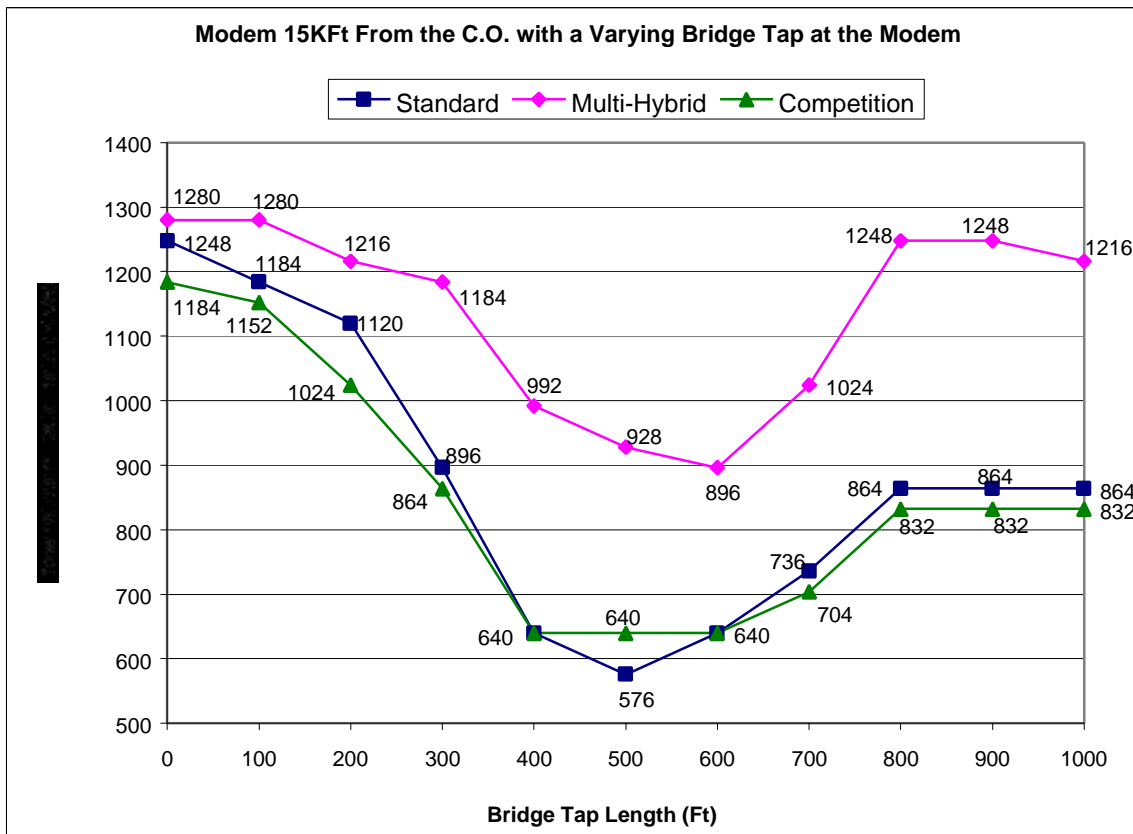
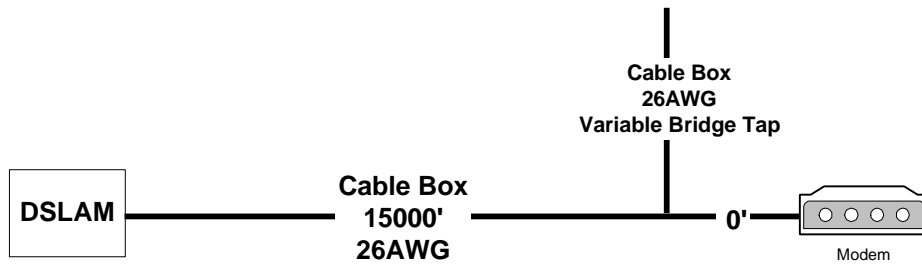




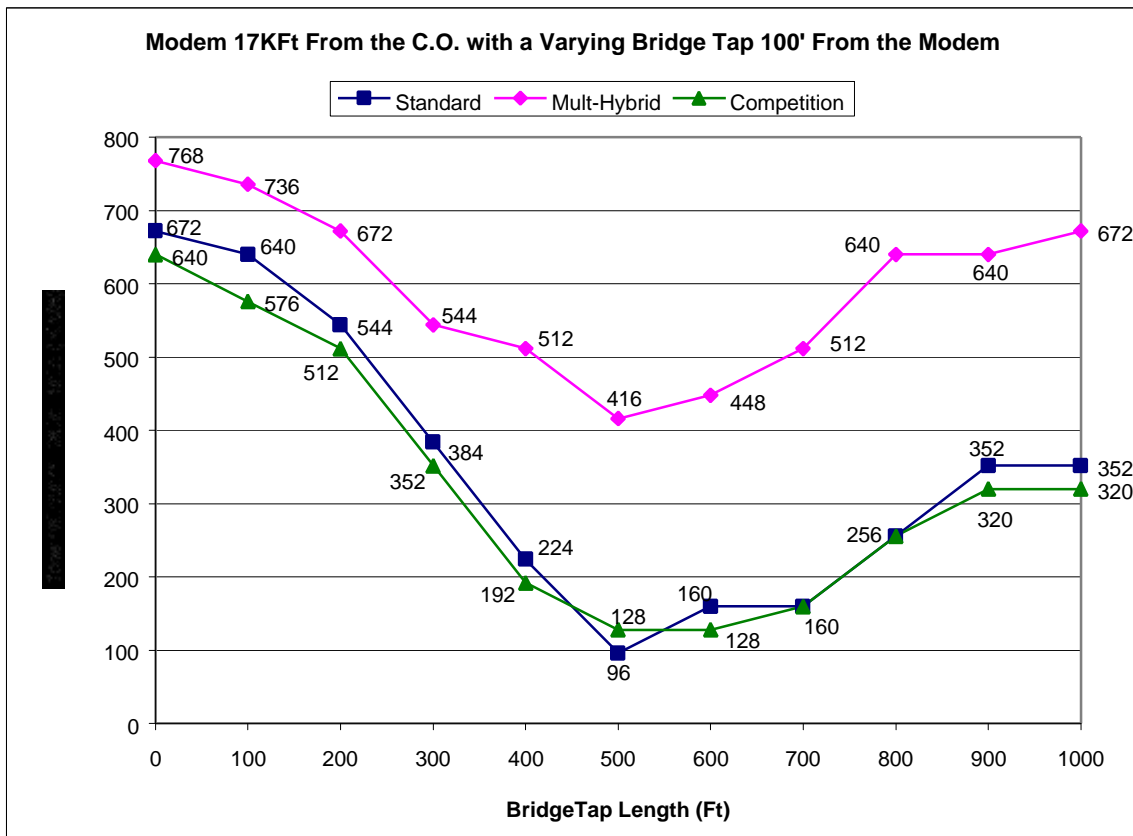
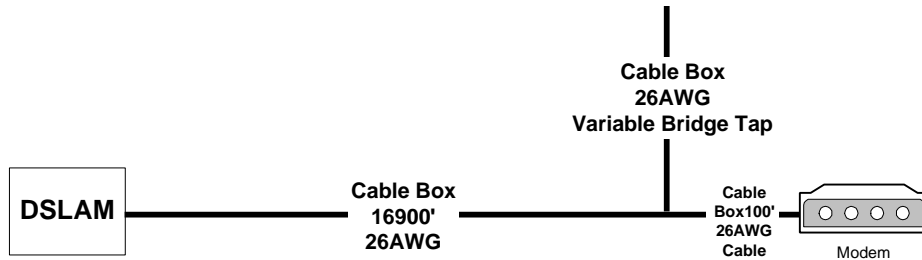
<b>Modem 17Kft from the C.O. with a Varying Bridge Tap at the Modem / -140dB of White Noise</b>											
<b>Modem Type</b>	<b>Bridge Tap Length (Ft)</b>										
	<b>0'</b>	<b>100'</b>	<b>200'</b>	<b>300'</b>	<b>400'</b>	<b>500'</b>	<b>600'</b>	<b>700'</b>	<b>800'</b>	<b>900'</b>	<b>1000'</b>
	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>
Standard	704/416	672/416	576/416	384/448	224/448	96/416	64/416	160/416	224/384	320/384	320/352
Multi-Hybrid	768/192	736/192	672/192	672/192	512/192	416/160	416/160	448/160	640/160	672/128	672/128
Competition	608/448	608/416	512/416	352/416	192/416	64/416	64/384	160/384	256/352	320/352	320/320



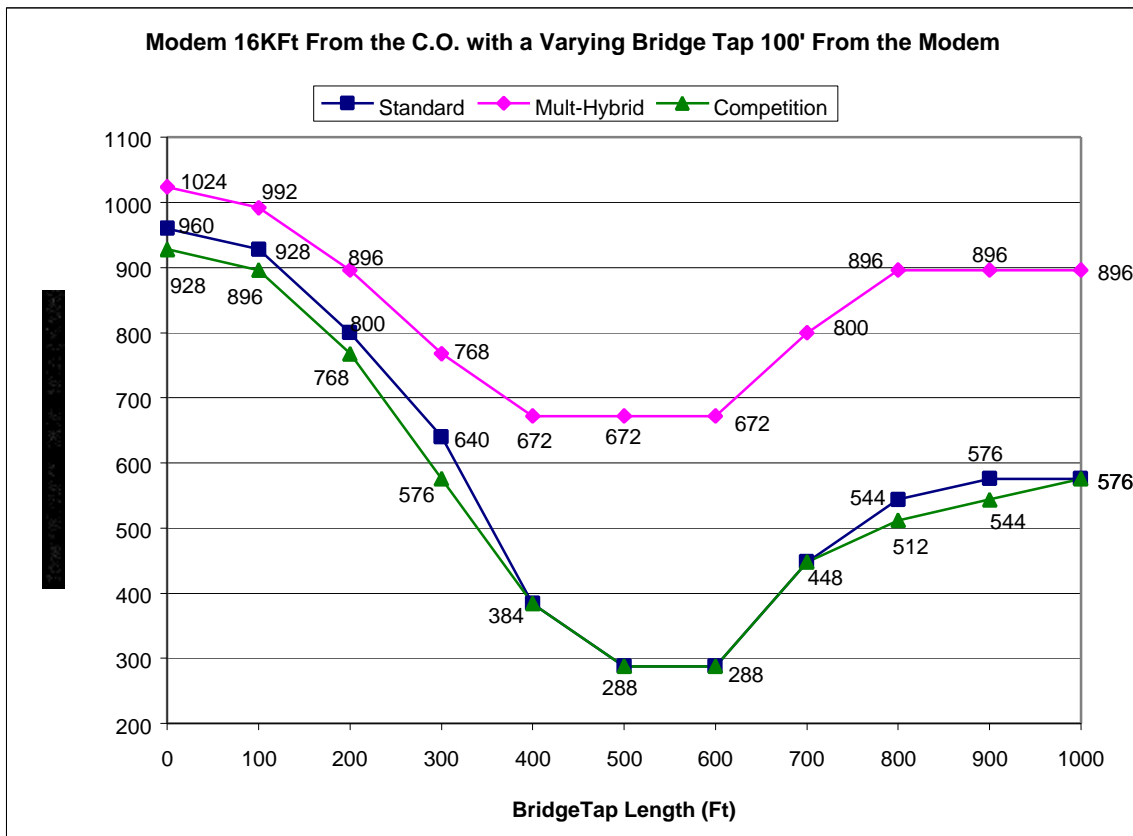
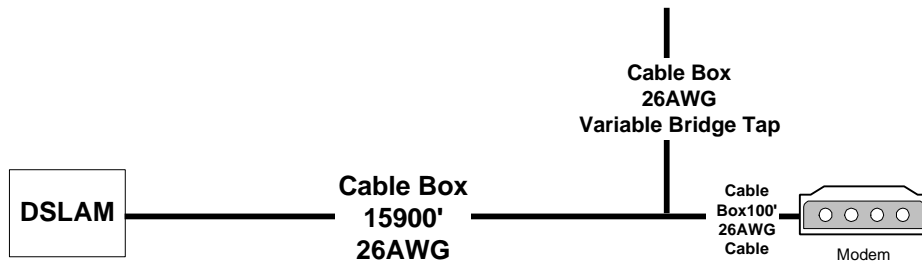
<b>Modem 16Kft from the C.O. with a Varying Bridge Tap at the Modem / -140dB of White Noise</b>											
<b>Modem Type</b>	<b>Bridge Tap Length (Ft)</b>										
	<b>0'</b>	<b>100'</b>	<b>200'</b>	<b>300'</b>	<b>400'</b>	<b>500'</b>	<b>600'</b>	<b>700'</b>	<b>800'</b>	<b>900'</b>	<b>1000'</b>
	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>
Standard	992/512	960/512	832/544	608/512	384/512	320/512	352/512	480/480	544/480	576/448	576/448
Multi-Hybrid	1088/288	1056/256	960/256	928/256	768/256	672/256	672/224	736/224	896/224	960/192	928/192
Competition	960/544	896/512	800/512	576/512	384/512	384/448	288/480	480/480	448/512	576/448	576/416



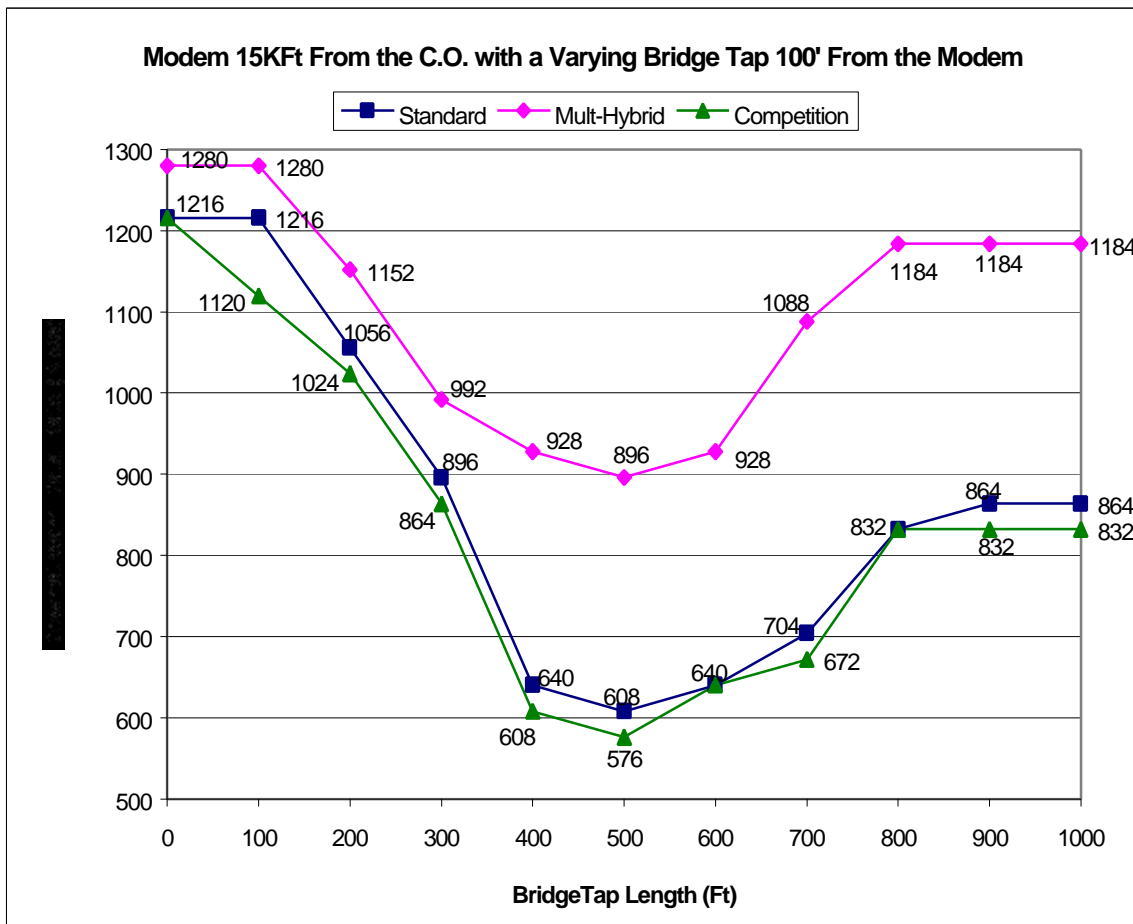
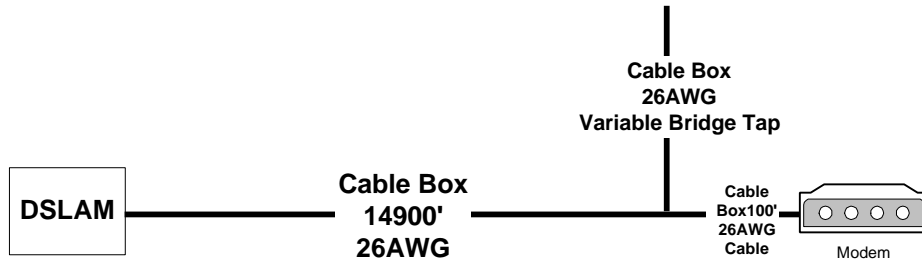
Modem 15Kft from the C.O. with a Varying Bridge Tap at the Modem / -140dB of White Noise											
Modem Type	Bridge Tap Length (Ft)										
	0'	100'	200'	300'	400'	500'	600'	700'	800'	900'	1000'
	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up
Standard	1248/608	1184/608	1120/544	896/640	640/640	576/608	640/608	736/576	864/544	864/544	864/544
Multi-Hybrid	1280/352	1280/352	1216/352	1184/352	992/352	928/320	896/320	1024/256	1248/256	1248/288	1216/288
Competition	1184/608	1152/608	1024/608	864/608	640/608	640/576	640/576	704/544	832/544	832/544	832/512



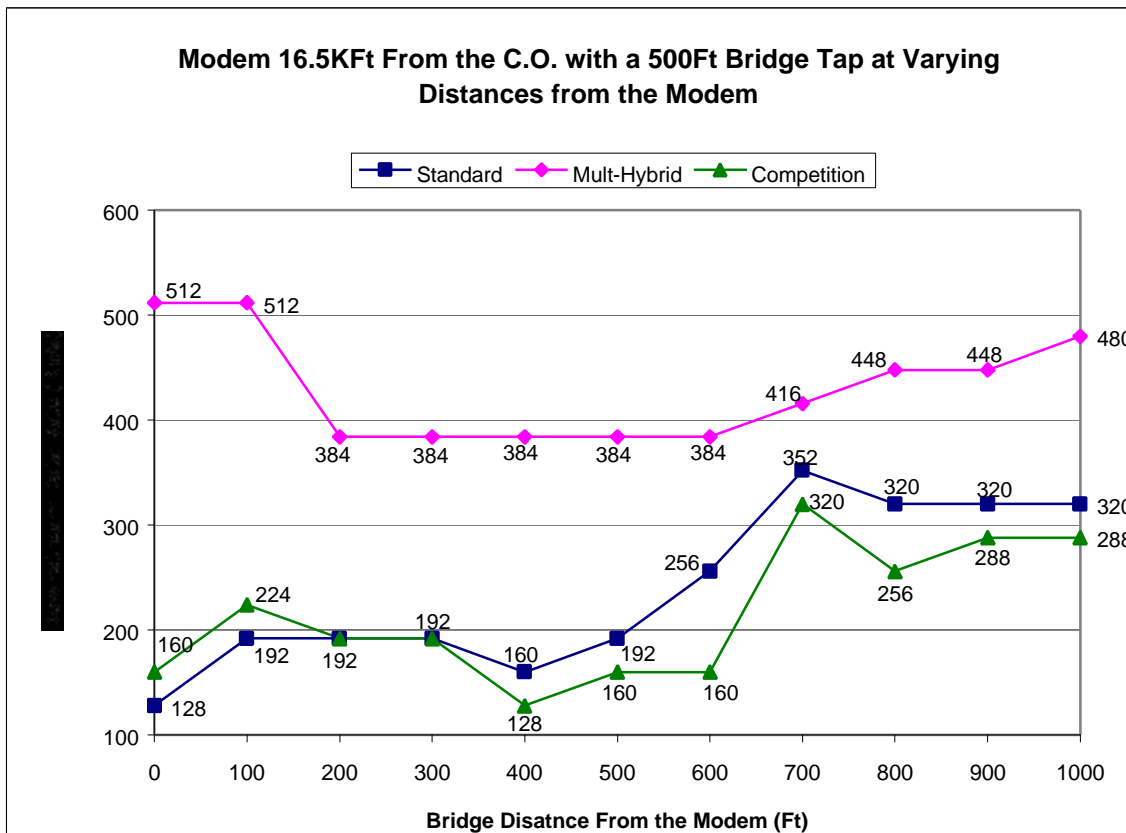
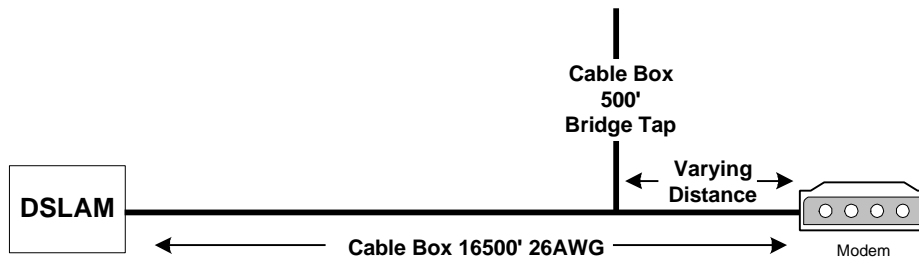
Modem 17KFt from the C.O. with a Varying Bridge Tap 100Ft from the Modem / -140dB of White Noise											
Modem Type	Bridge Tap Length (Ft)										
	0'	100'	200'	300'	400'	500'	600'	700'	800'	900'	1000'
	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up
Standard	672/416	640/416	544/448	384/448	224/448	96/416	160/416	160/416	256/384	352/384	352/352
Multi-Hybrid	768/192	736/192	672/192	544/192	512/192	416/160	448/160	512/160	640/160	640/128	672/128
Competition	640/448	576/416	512/416	352/416	192/416	128/352	128/384	160/384	256/352	320/352	320/352



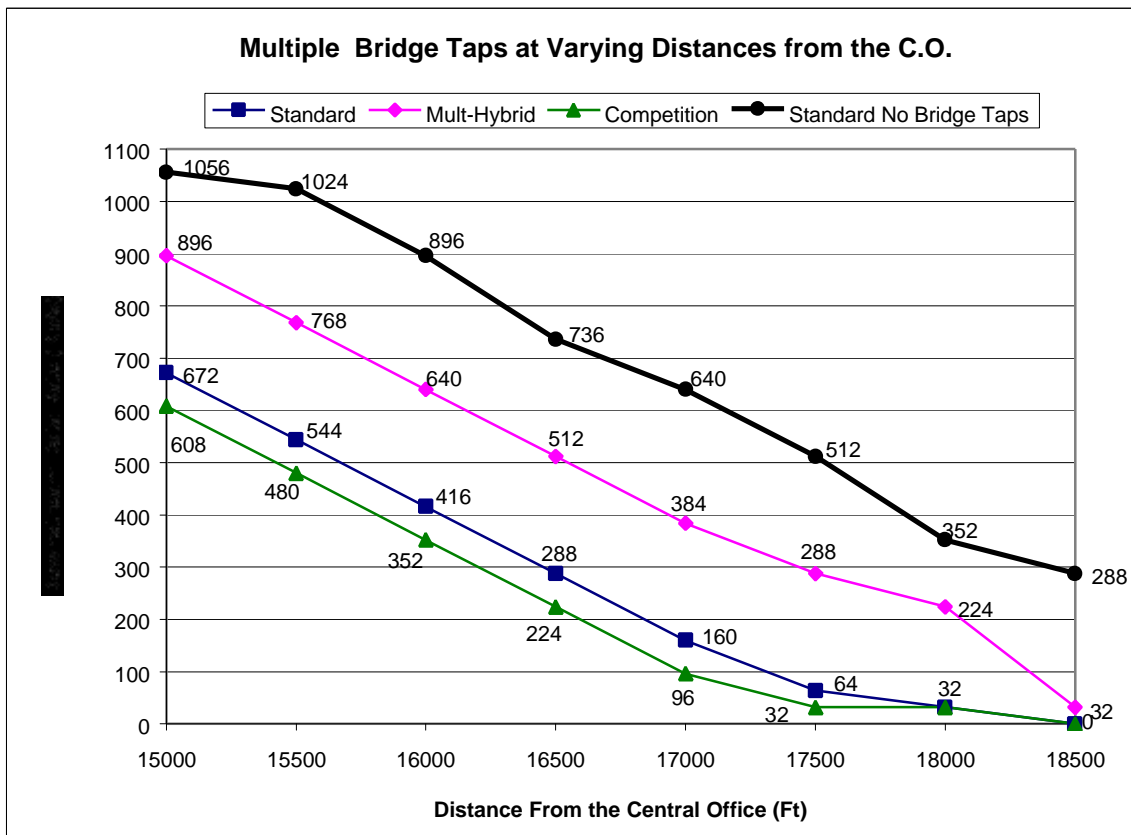
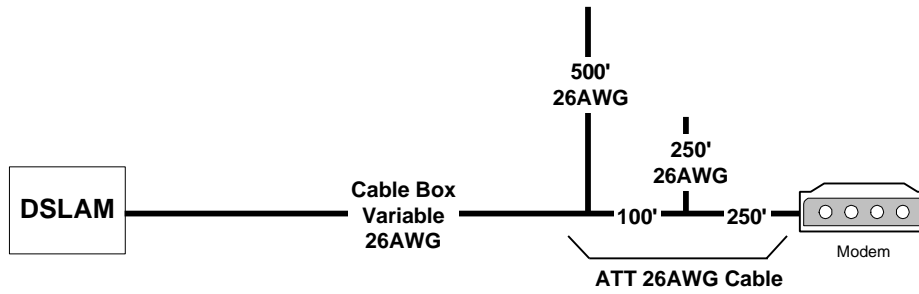
<b>Modem 16Kft from the C.O. with a Varying Bridge Tap 100ft from the Modem / -140dB of White Noise</b>											
<b>Modem Type</b>	<b>Bridge Tap Length (Ft)</b>										
	0'	100'	200'	300'	400'	500'	600'	700'	800'	900'	1000'
	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up
Standard	960/512	928/512	800/544	640/544	384/544	288/512	288/512	448/512	544/480	576/448	576/448
Multi-Hybrid	1024/288	992/288	896/288	768/256	672/256	672/256	672/256	800/224	896/224	896/224	896/192
Competition	928/512	896/512	768/512	576/512	384/512	288/480	288/480	448/480	512/480	544/448	576/416



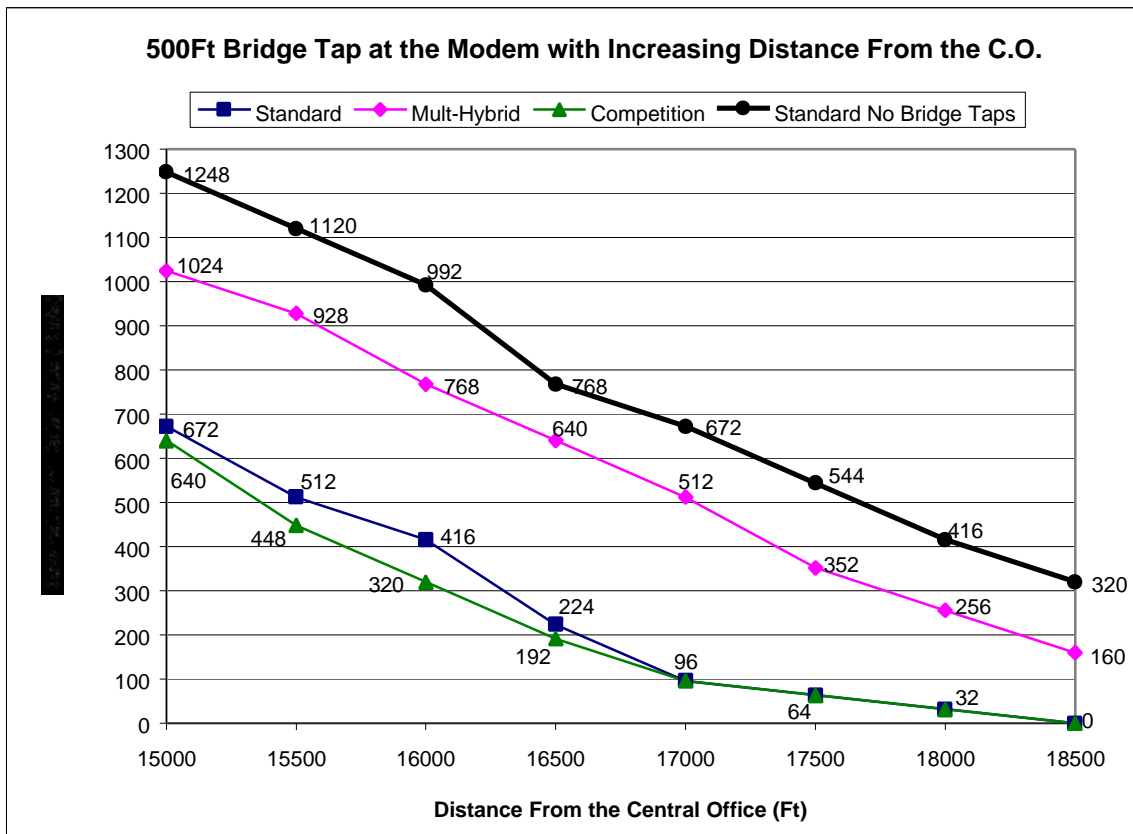
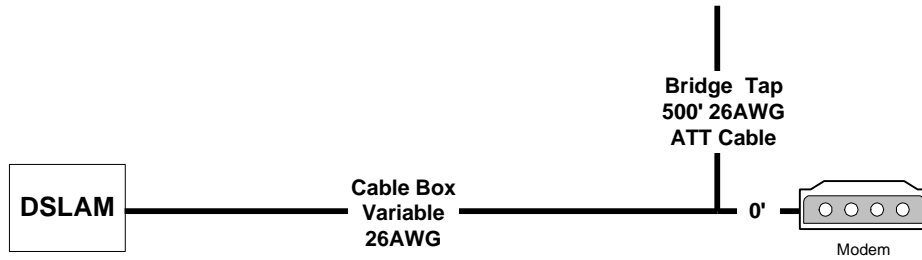
Modem 15Kft from the C.O. with a Varying Bridge Tap 100Ft from the Modem / -140dB of White Noise											
Modem Type	Bridge Tap Length (Ft)										
	0'	100'	200'	300'	400'	500'	600'	700'	800'	900'	1000'
	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up
Standard	1216/608	1216/576	1056/640	896/608	640/608	608/608	640/608	704/576	832/576	864/544	864/544
Multi-Hybrid	1280/384	1280/352	1152/352	992/352	928/352	896/352	928/320	1088/320	1184/320	1184/288	1184/288
Competition	1216/608	1120/608	1024/608	864/608	608/576	576/576	640/576	672/544	832/544	832/544	832/512



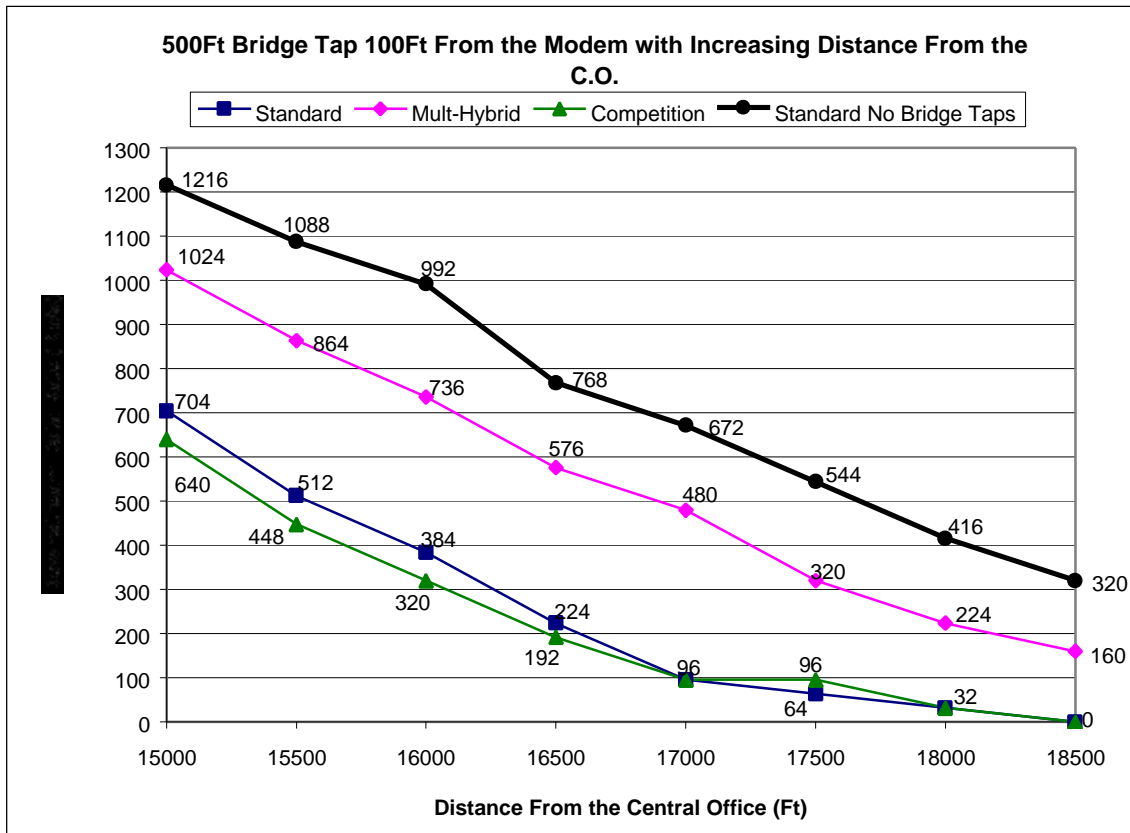
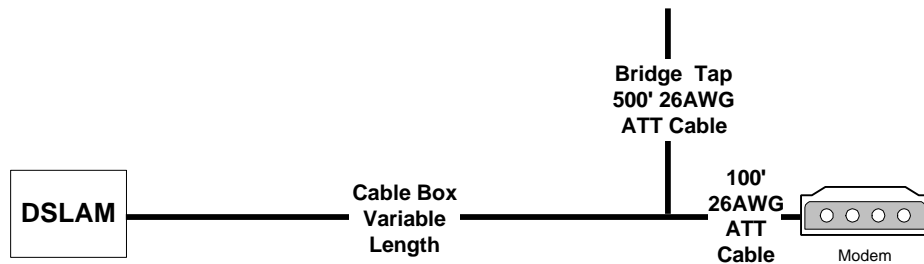
<b>Modem 16.5Kft From the C.O. with a 500Ft Bridge Tap at varying Distances from the Modem/ -140dB of White Noise</b>											
<b>Modem Type</b>	<b>Bridge Tap Length (Ft)</b>										
	<b>0'</b>	<b>100'</b>	<b>200'</b>	<b>300'</b>	<b>400'</b>	<b>500'</b>	<b>600'</b>	<b>700'</b>	<b>800'</b>	<b>900'</b>	<b>1000'</b>
	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>	<b>Down/Up</b>
Standard	128/480	192/480	192/480	192/416	160/480	192/480	256/480	352/448	320/480	320/480	320/480
Multi-Hybrid	512/224	512/224	384/224	384/224	384/224	384/224	384/224	416/224	448/224	448/224	480/224
Competition	160/448	224/416	192/448	192/448	128/448	160/448	160/448	320/384	256/448	288/448	288/448



Multiple Bridge Taps at Varying Distances from the C.O./ -140dB of White Noise								
Modem Type	Bridge Tap Length (Ft)							
	15000'	15500'	16000'	16500'	17000'	17500'	18000'	18500'
	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up
Standard	672/544	544/480	416/448	288/416	160/352	64/320	32/288	No Sync
Multi-Hybrid	896/288	768/224	640/192	512/160	384/128	288/96	224/64	32/192
Competition	608/512	480/480	352/416	224/384	96/352	32/288	32/256	No Sync

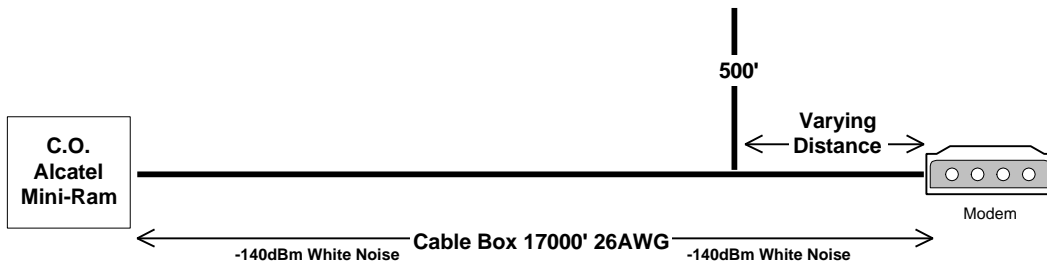


500Ft Bridge Tap at the Modem with Increasing Distance From the C.O. / -140dB of White Noise								
Modem Type	Bridge Tap Length (Ft)							
	15000'	15500'	16000'	16500'	17000'	17500'	18000'	18500'
	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up
Standard	672/608	512/544	416/512	224/448	96/416	64/352	32/320	No Sync
Multi-Hybrid	1024/320	928/256	768/224	640/192	512/160	352/128	256/64	160/32
Competition	640/544	448/512	320/480	192/416	96/384	64/320	32/256	No Sync

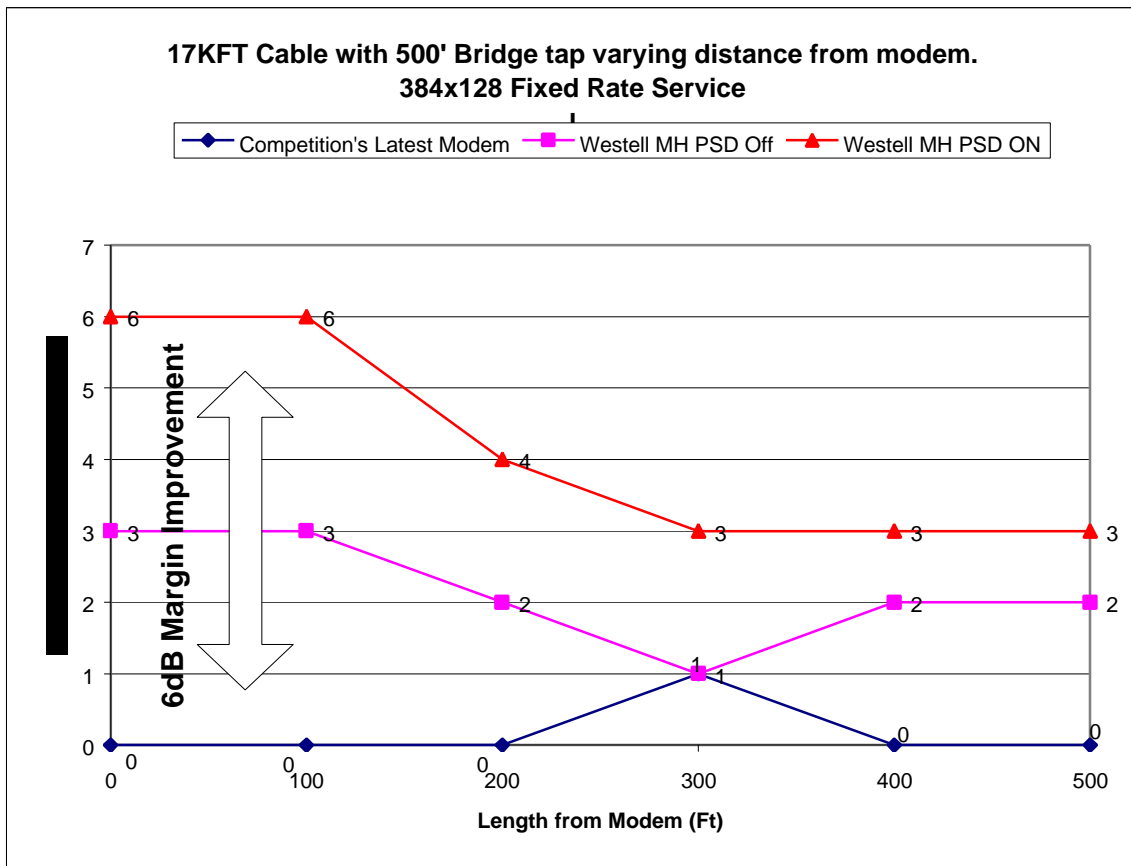


500Ft Bridge Tap 100Ft From the Modem with Increasing Distance From the C.O./ -140dB of White Noise								
Modem Type	Bridge Tap Length (Ft)							
	15000'	15500'	16000'	16500'	17000'	17500'	18000'	18500'
	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up
Standard	704/576	512/544	384/480	224/448	96/384	64/352	32/320	No Sync
Multi-Hybrid	1024/320	864/288	736/224	576/192	480/160	320/128	224/96	160/64
Competition	640/544	448/512	320/480	192/416	96/384	96/288	32/256	No Sync

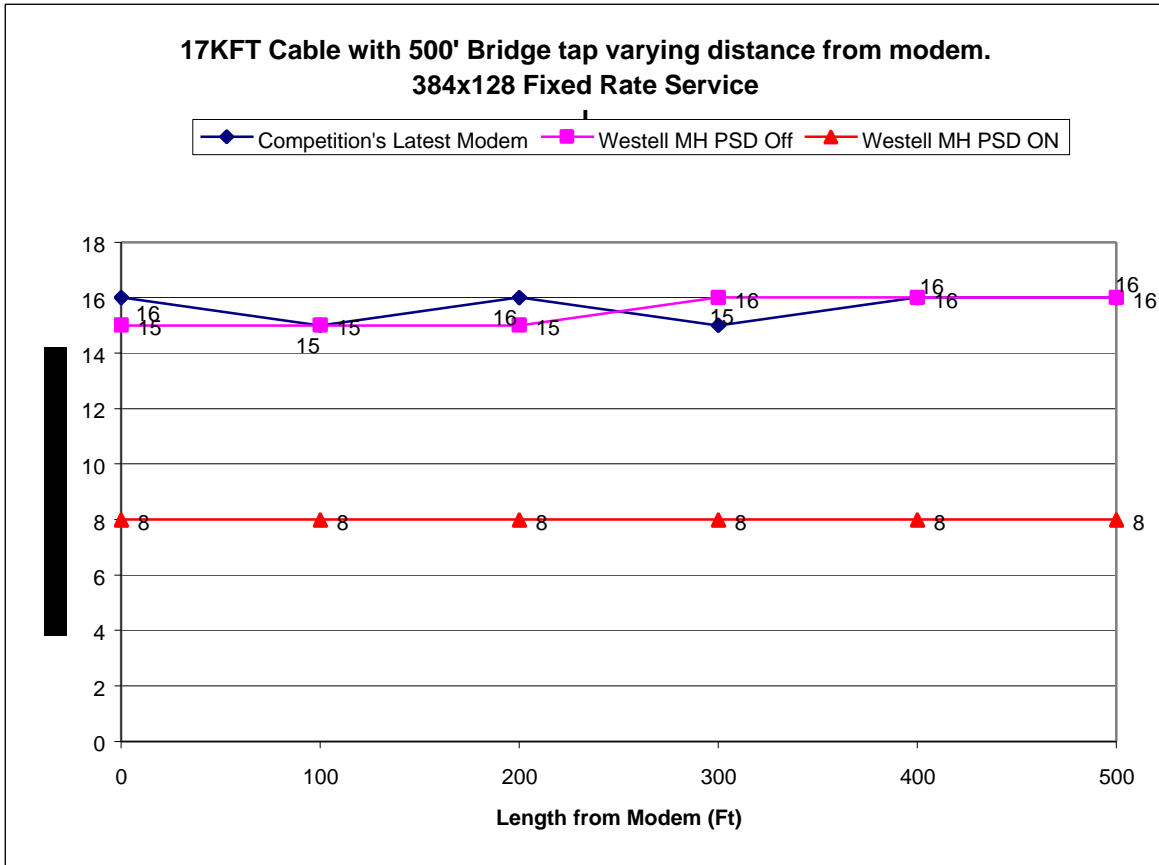
# Fixed Rate Services With Westell's Multi-Hybrid Modem

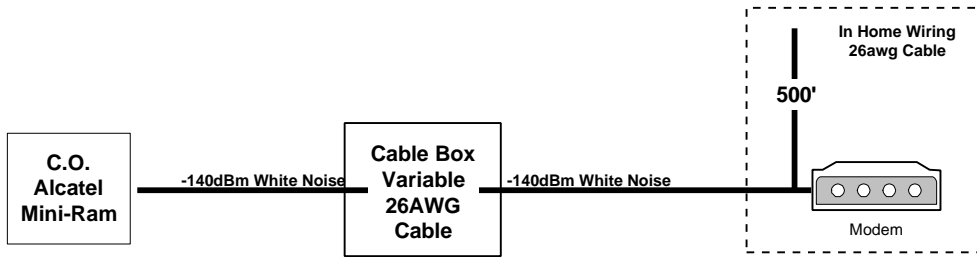


## Downstream

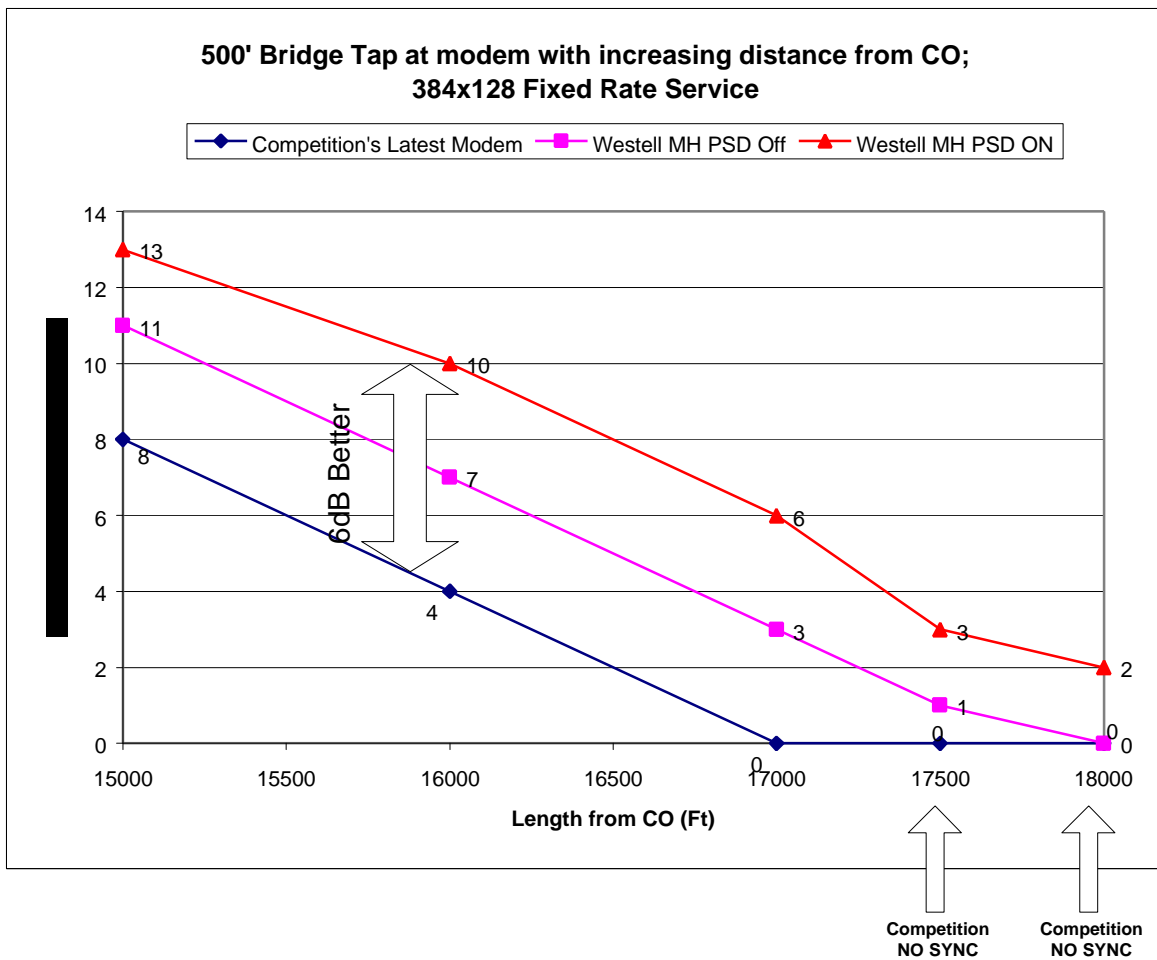


# Upstream

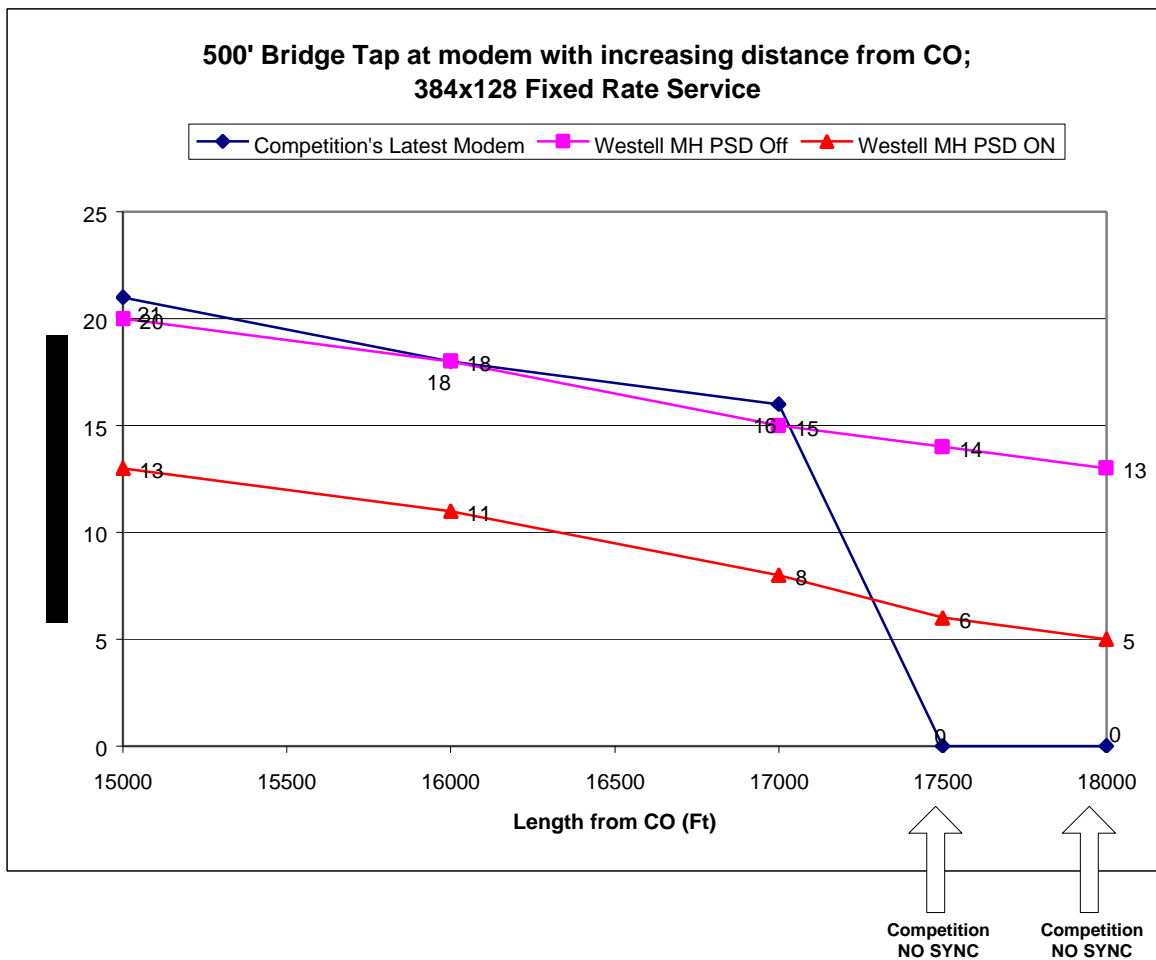


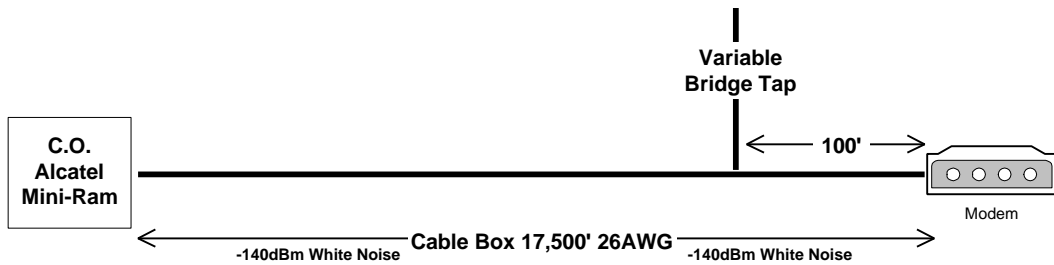


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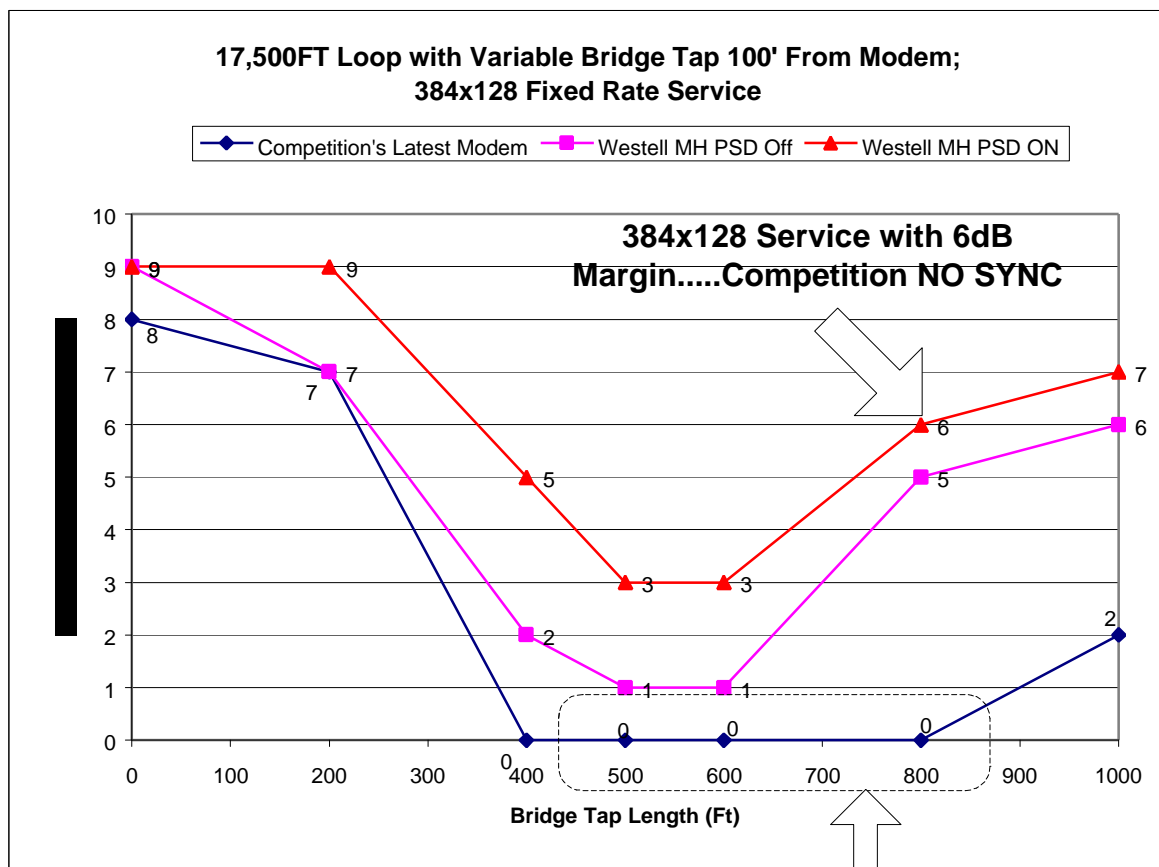


# Upstream



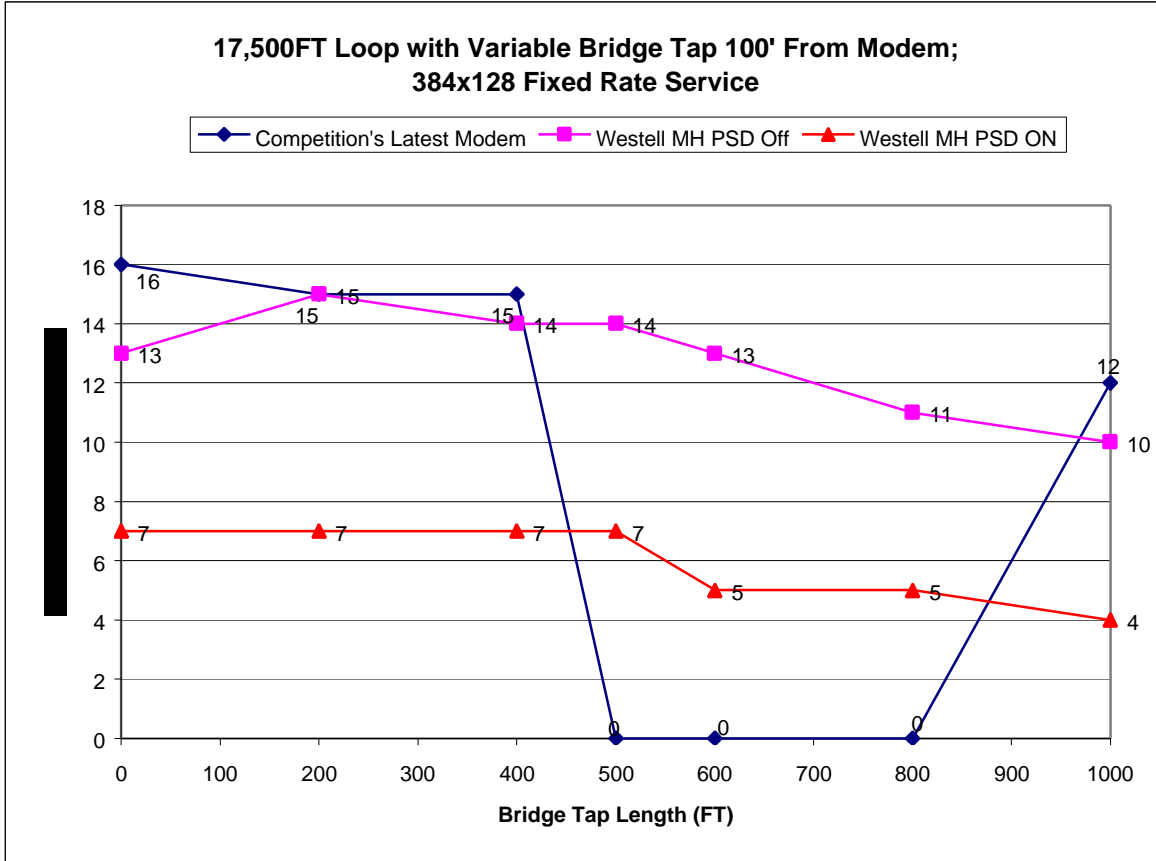


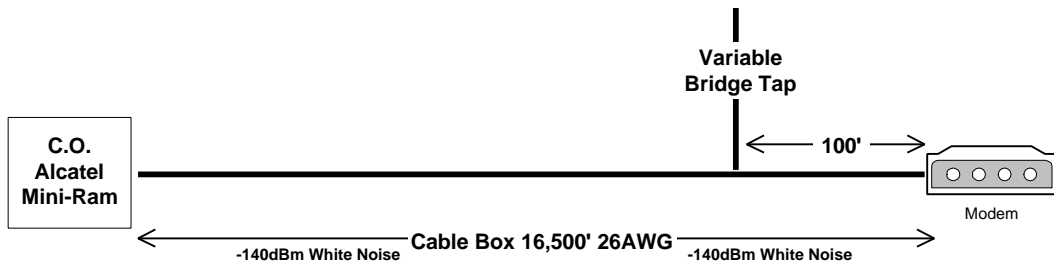
## Downstream



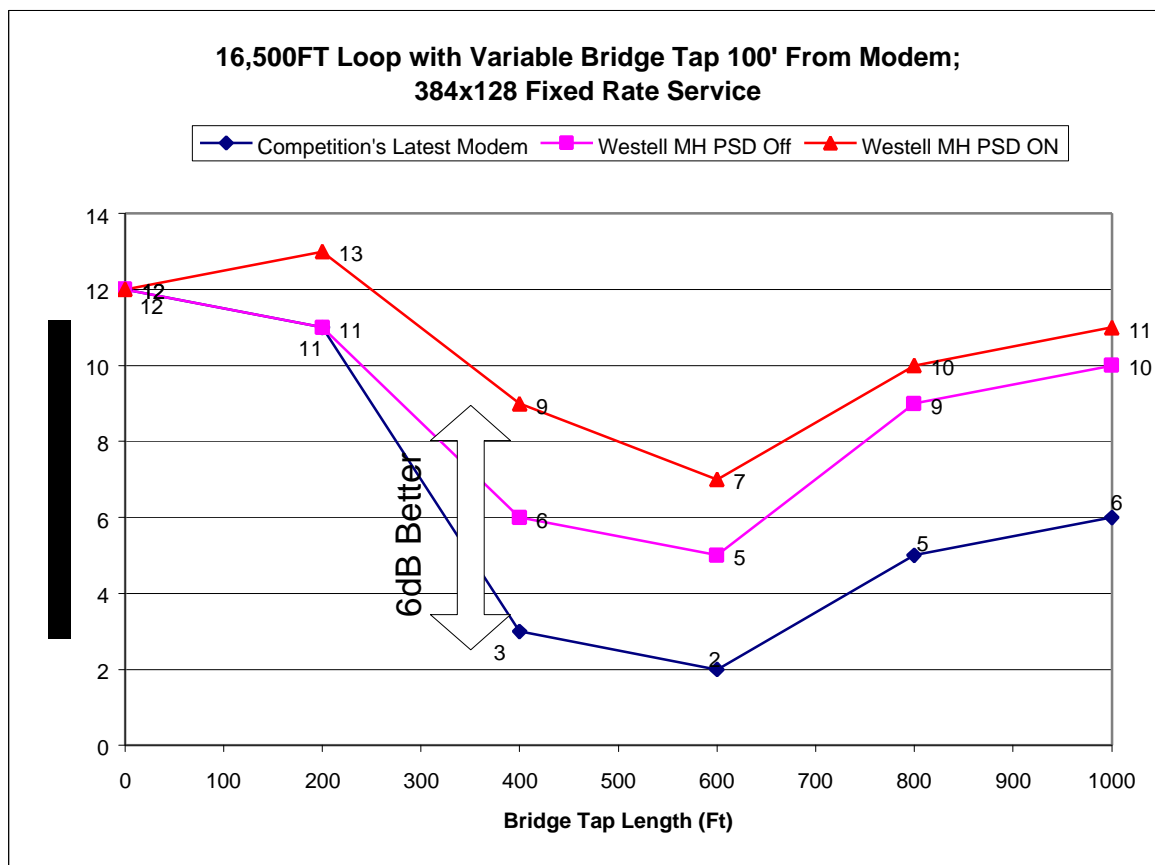
Competition  
NO SYNC

# Upstream

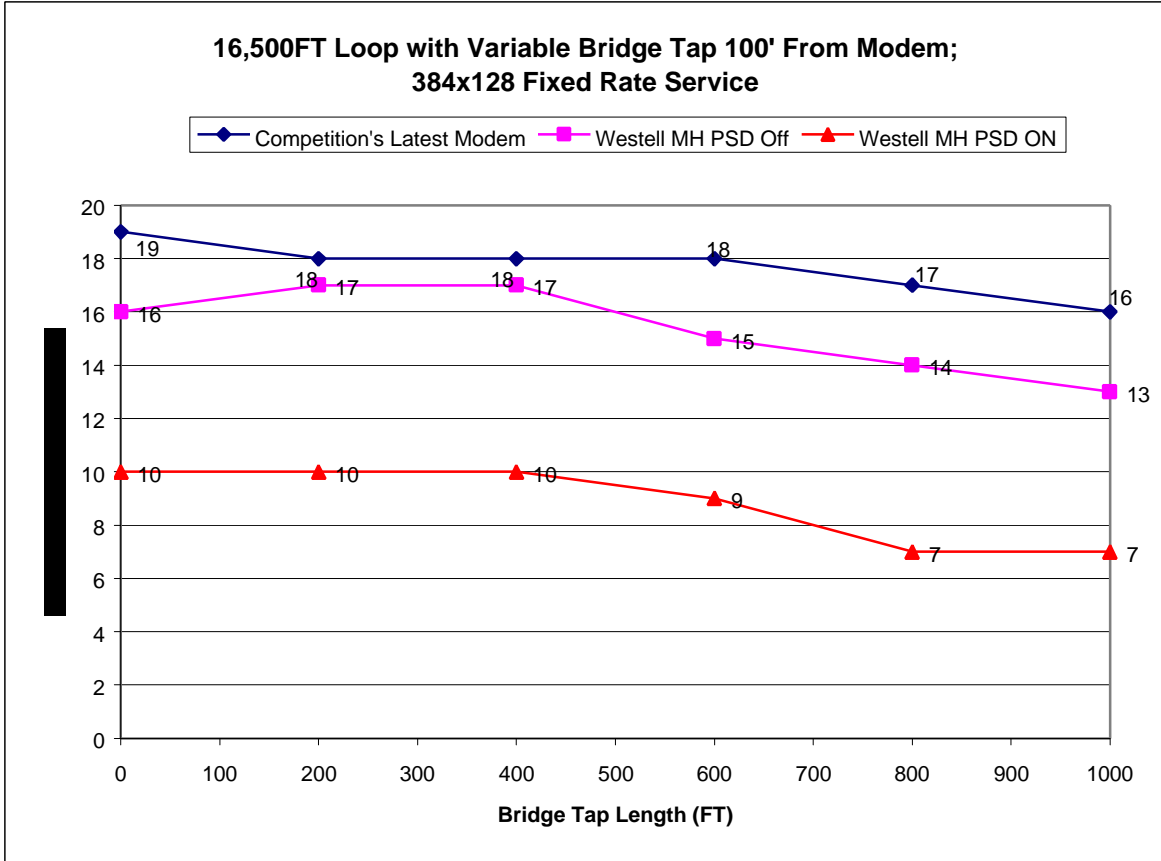


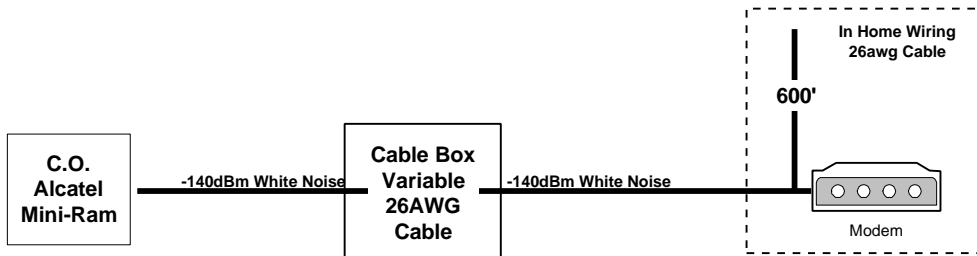


## Downstream

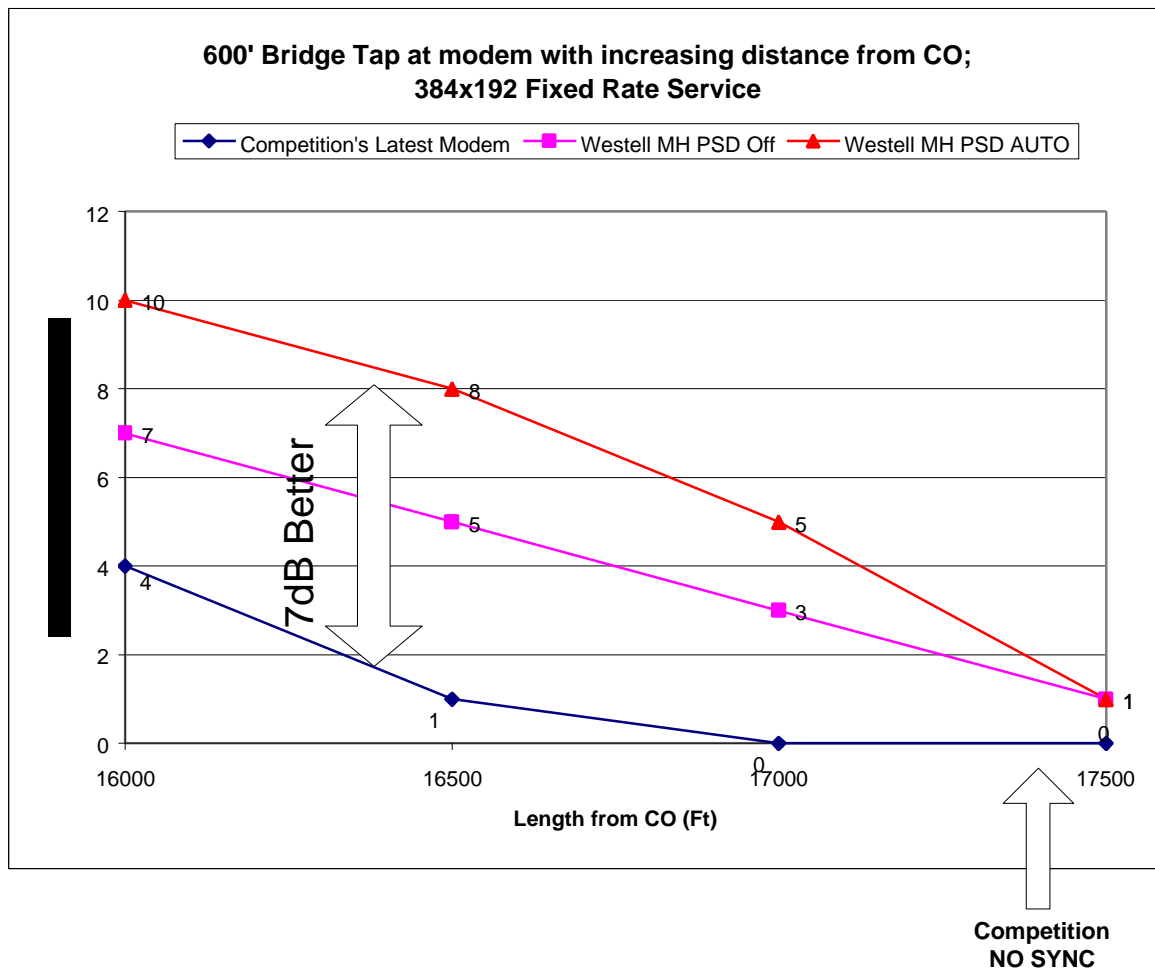


# Upstream

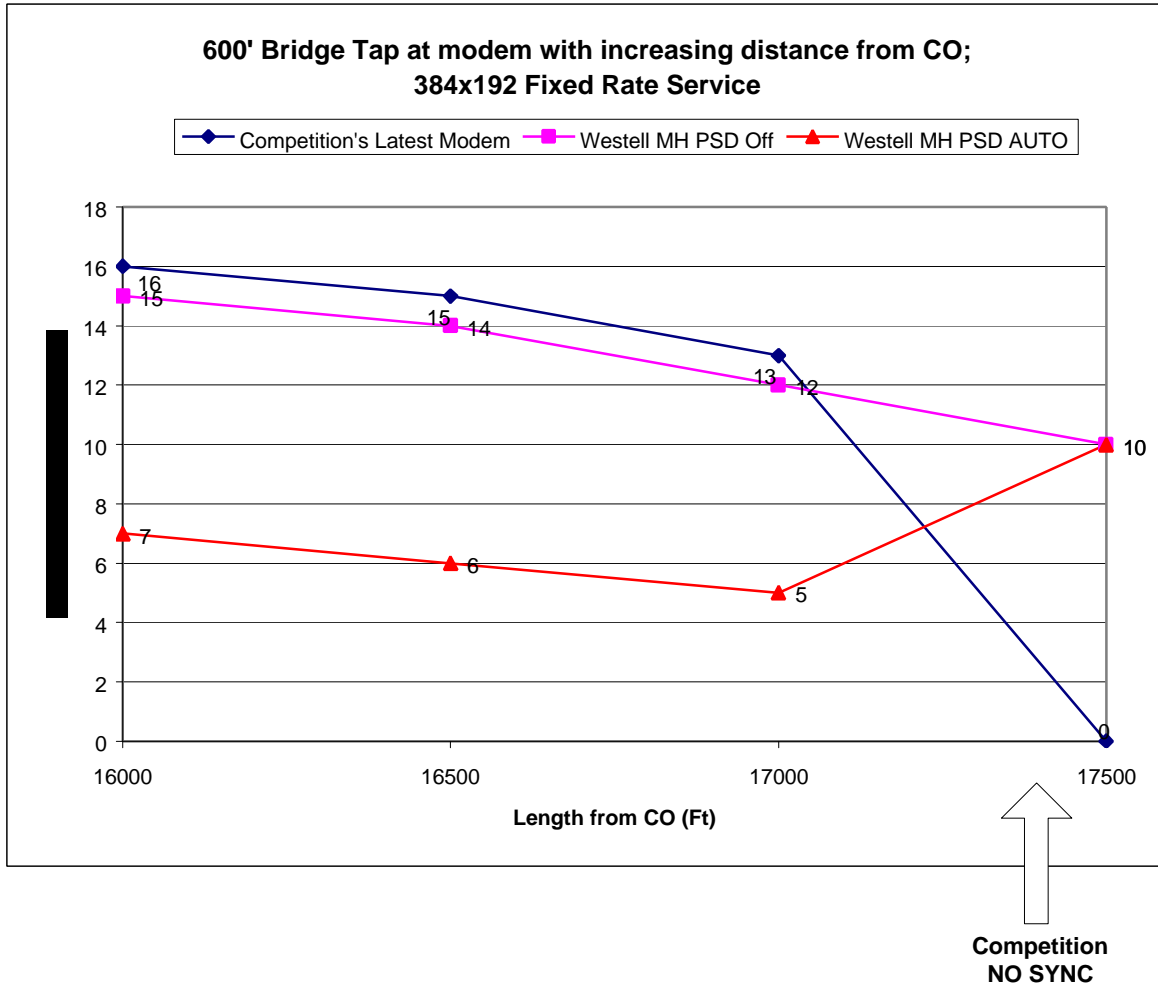




## Downstream (384x192 Fixed Rate Service)



## Upstream (384x192 Fixed Rate Service)

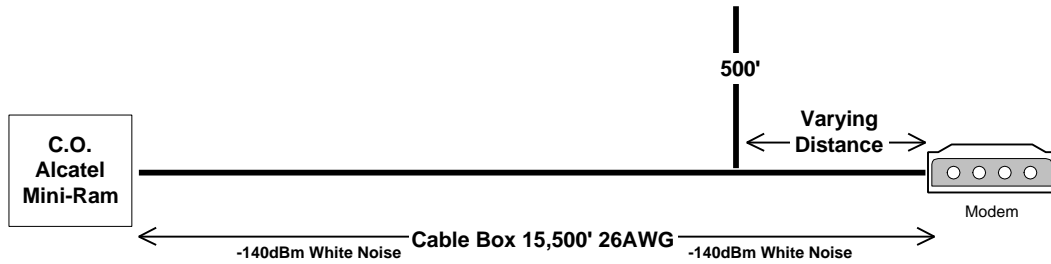


**Note: 384x192 Service is still downstream limited on long loops with Bridge Taps. Upstream Margins are still acceptable even with PSD shaping enabled.**

**This service offering can be on long loops with bridge taps that require greater upstream data rates for VOIP services**

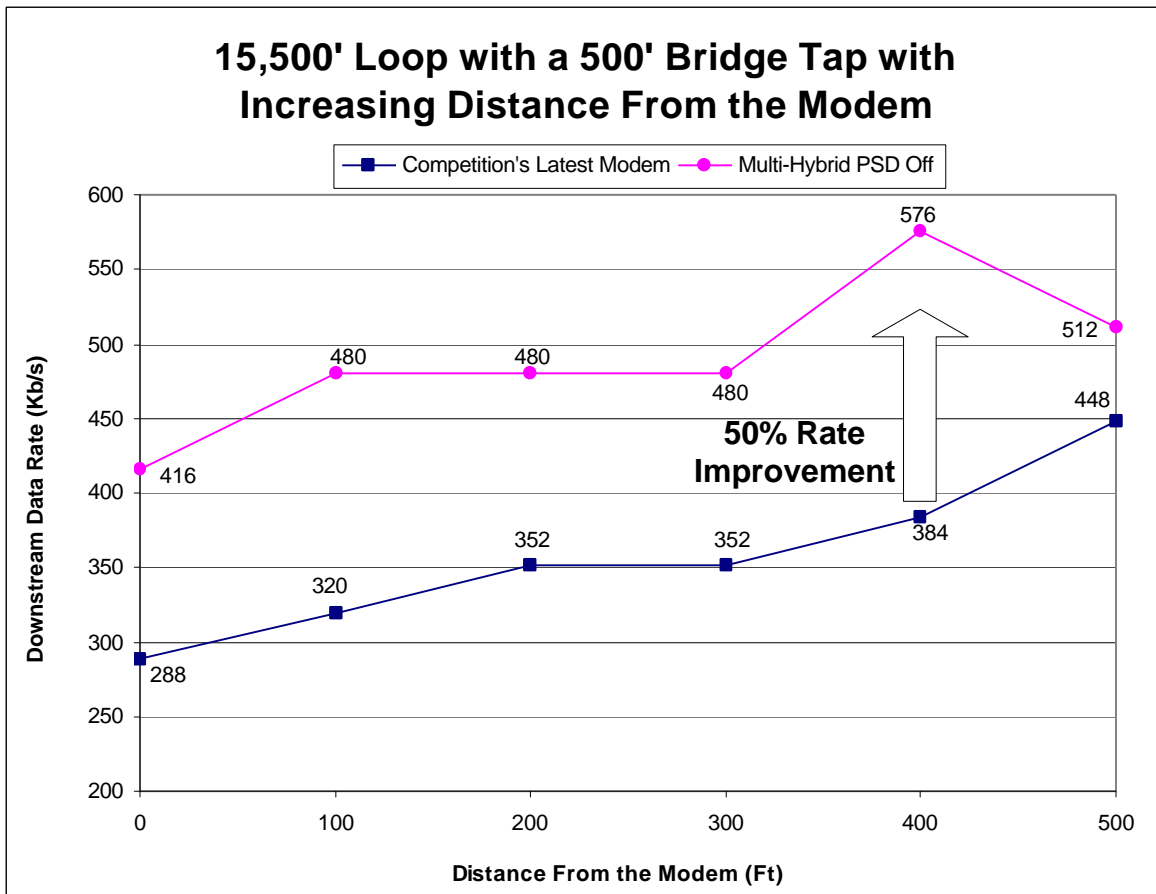
# Crosstalk Performance of Westell's Multi-Hybrid Modem

## 24 DSL NEXT (-53.8) Plus -140dBm White Noise



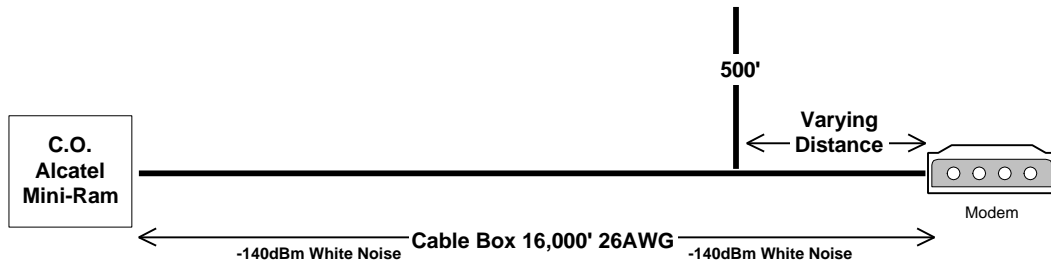
## **Downstream**

24 DSL NEXT (-53.8)/ -140dBm White Noise



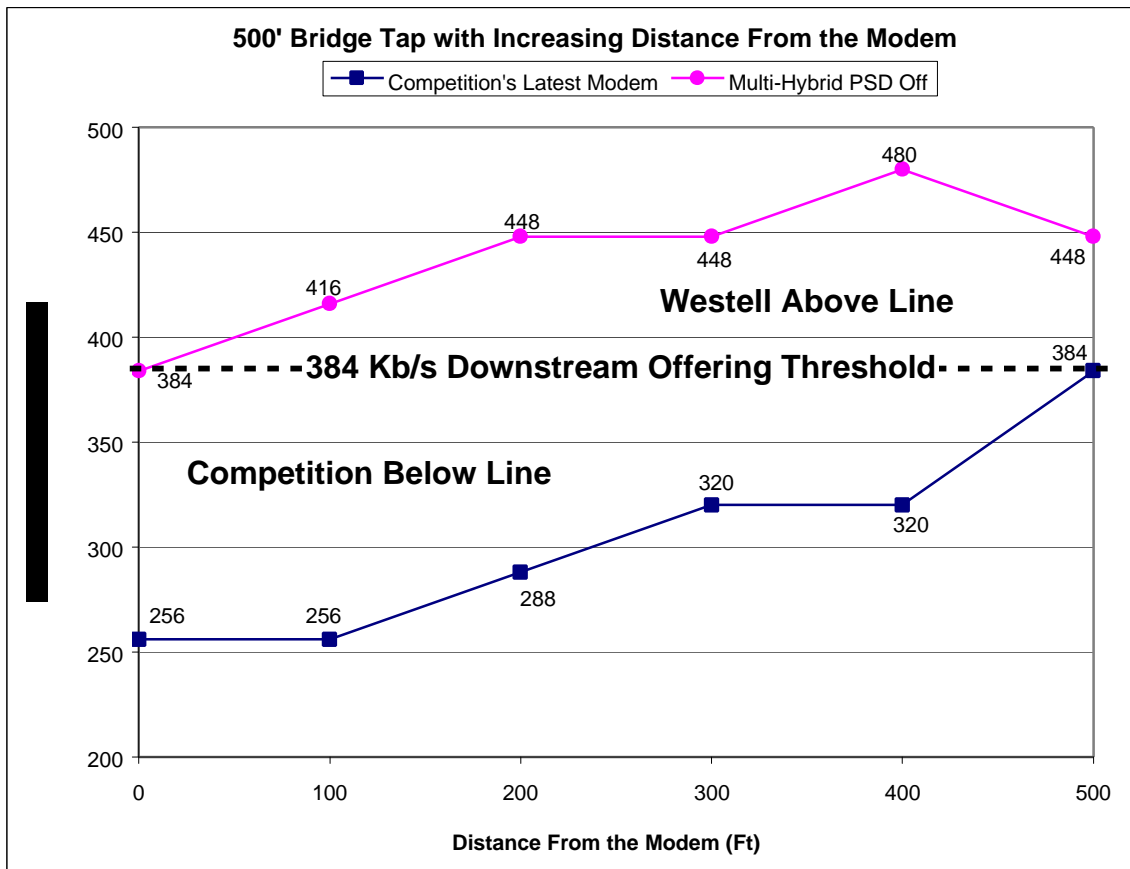
Noise is injected at both the -C and the -R. The noise brought the upstream data rate down to 160Kb/s. PSD shaping was disabled on this loop. The multi-hybrid routine by itself still realizes significant improvement in the downstream data rate.

## 24 DSL NEXT (-53.8) Plus -140dBm White Noise



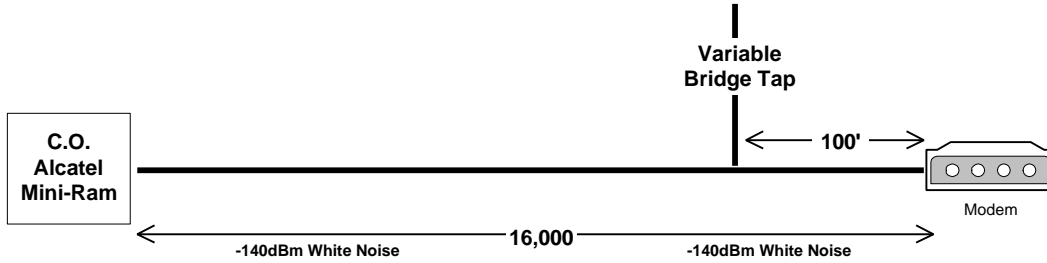
## Downstream

24 DSL NEXT (-53.8)/ -140dBm White Noise



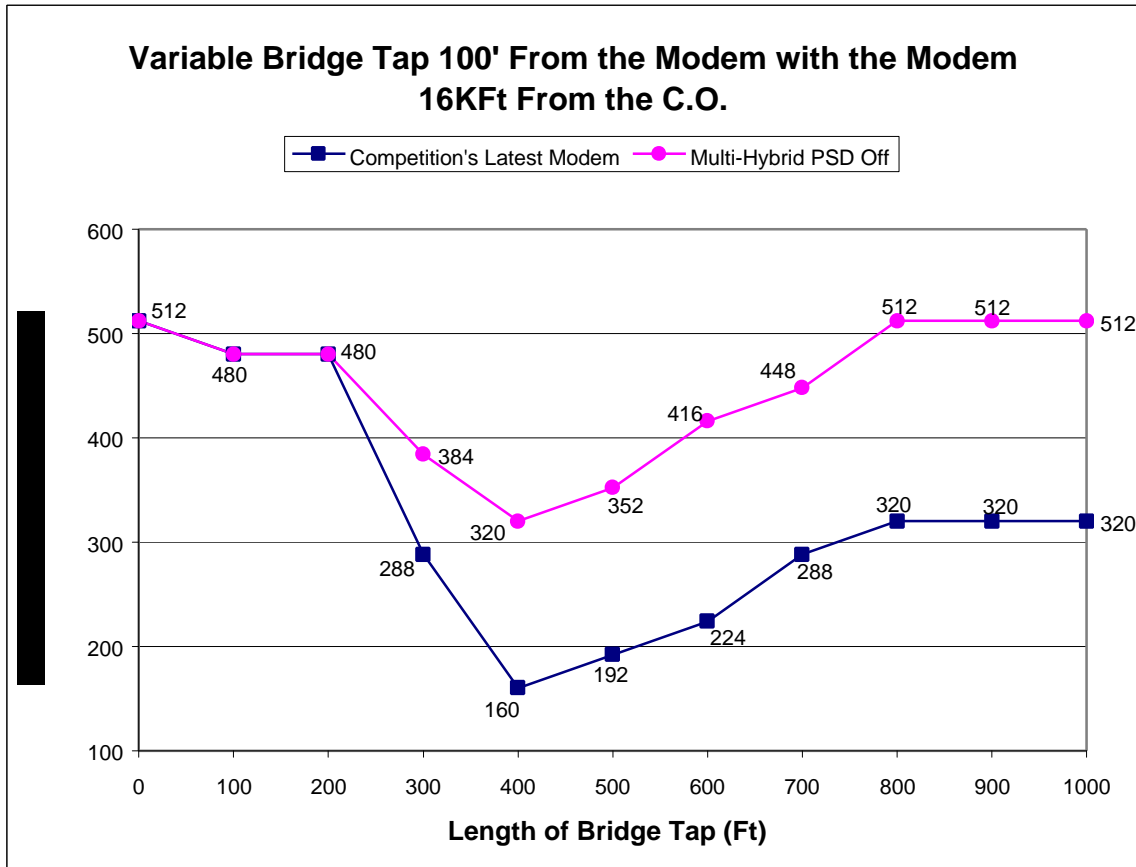
Noise is injected at both the -C and the -R. The noise brought the upstream data rate down to 160Kb/s. PSD shaping was disabled on this loop. The multi-hybrid routine by itself still realizes significant improvement in the downstream data rate

## 24 DSL NEXT (-53.8) Plus -140dBm White Noise



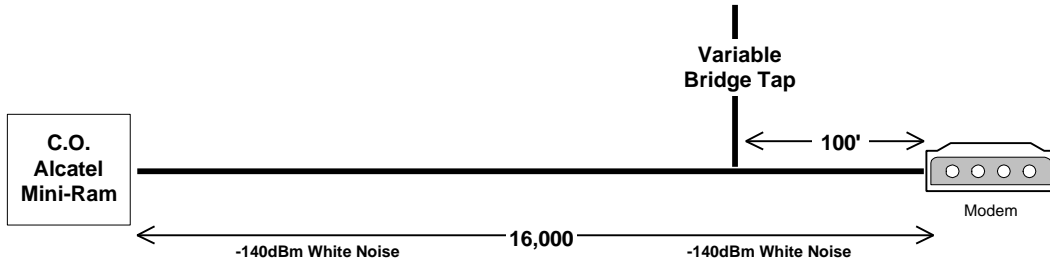
## Downstream

24 DSL NEXT (-53.8)/ -140dBm White Noise



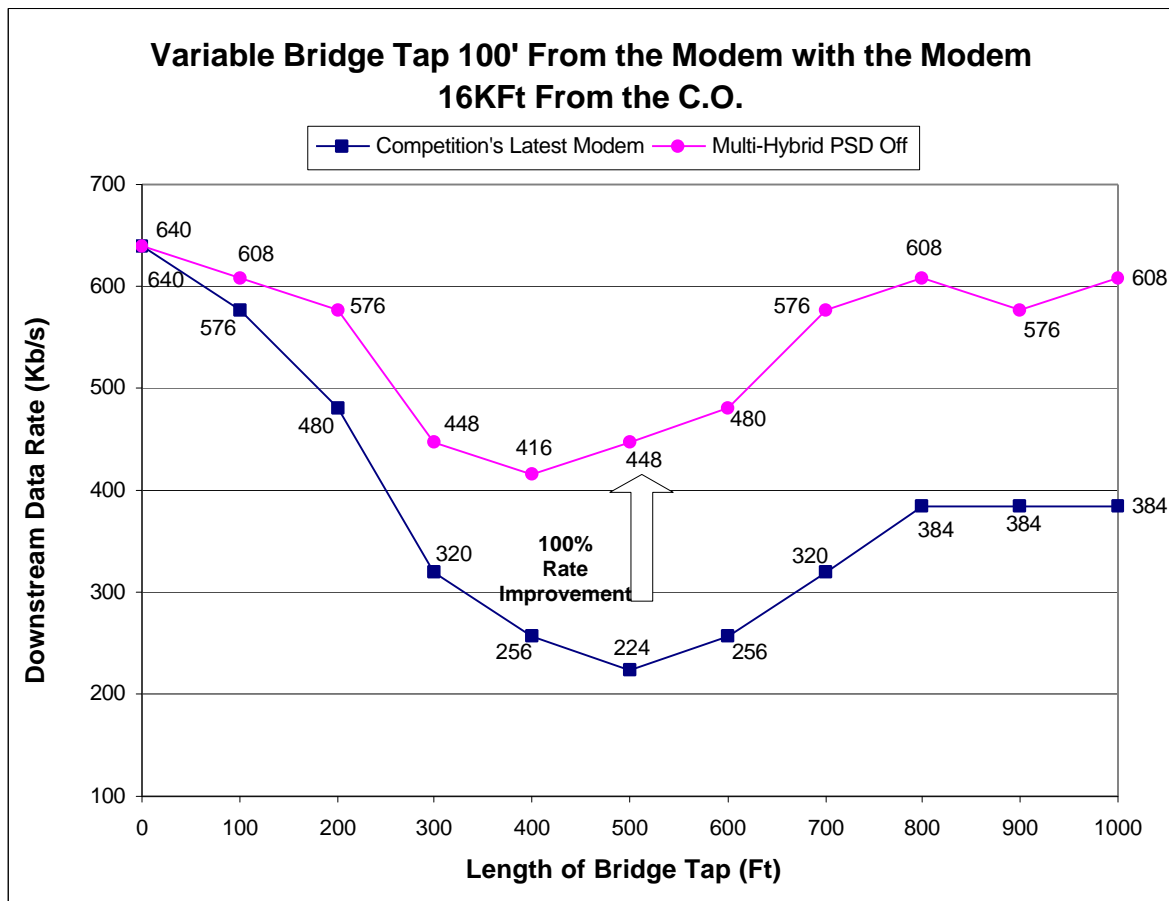
Noise is injected at both the -C and the -R. The noise brought the upstream data rate down to 160Kb/s. PSD shaping was disabled on this loop. The multi-hybrid routine by itself still realizes significant improvement in the downstream data rate

# 10 DSL NEXT (-56.1) Plus -140dBm White Noise

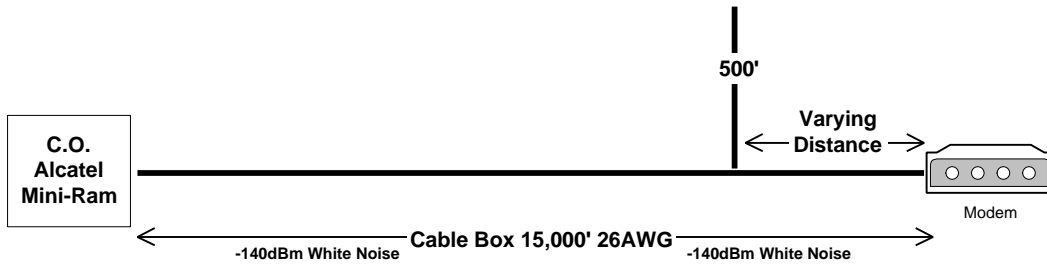


## Downstream

10 DSL NEXT (-56.1) with -140dBm White Noise

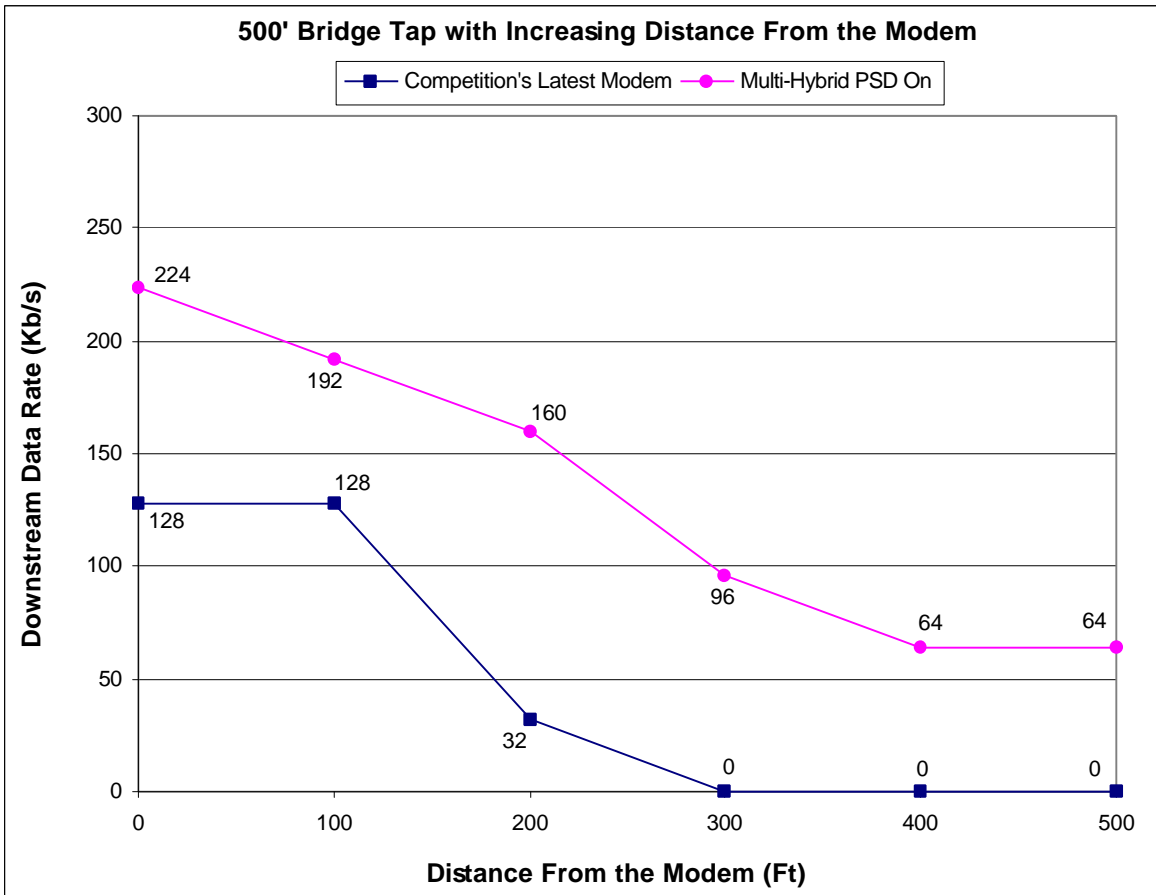


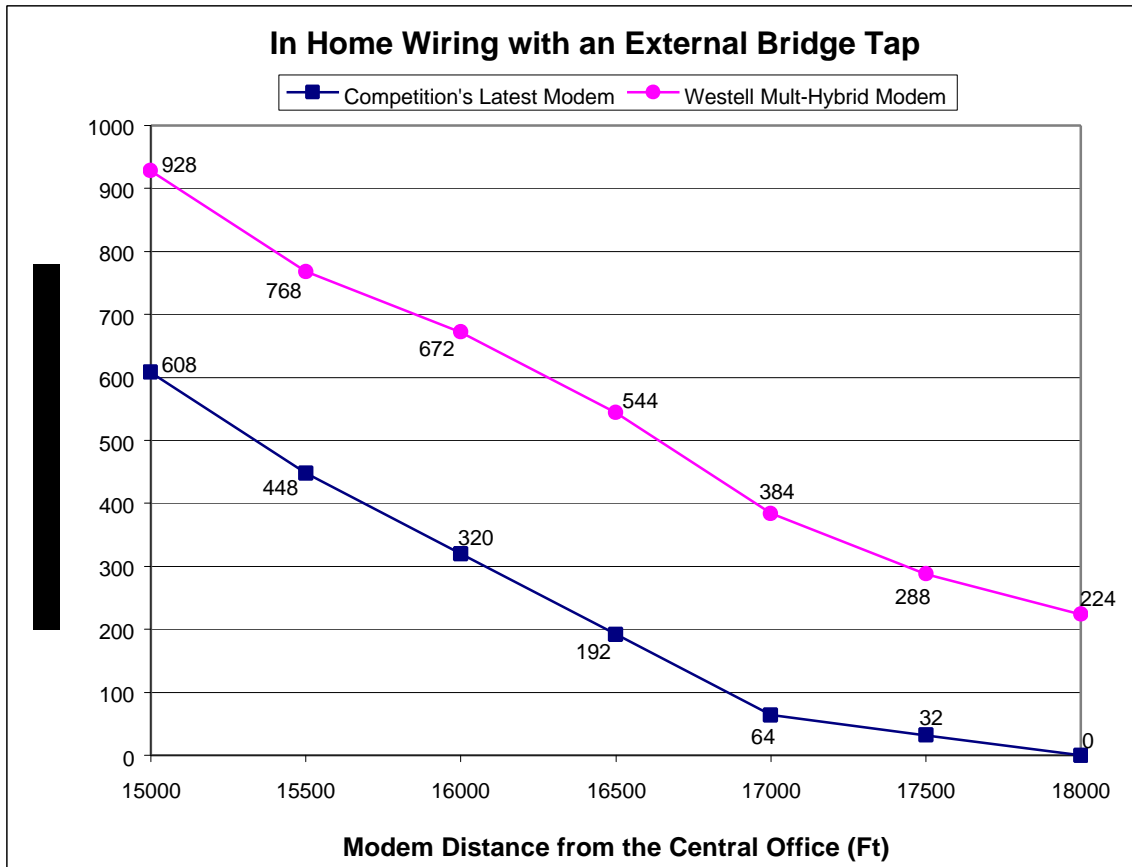
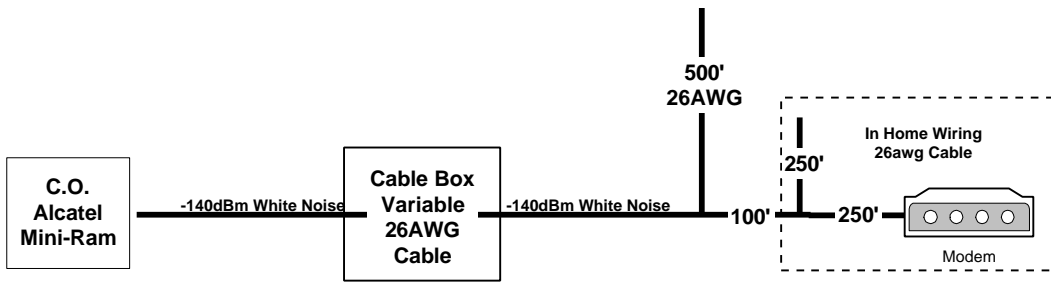
## 5 T1 AMI NEXT (-49.6) Plus -140dBm White Noise



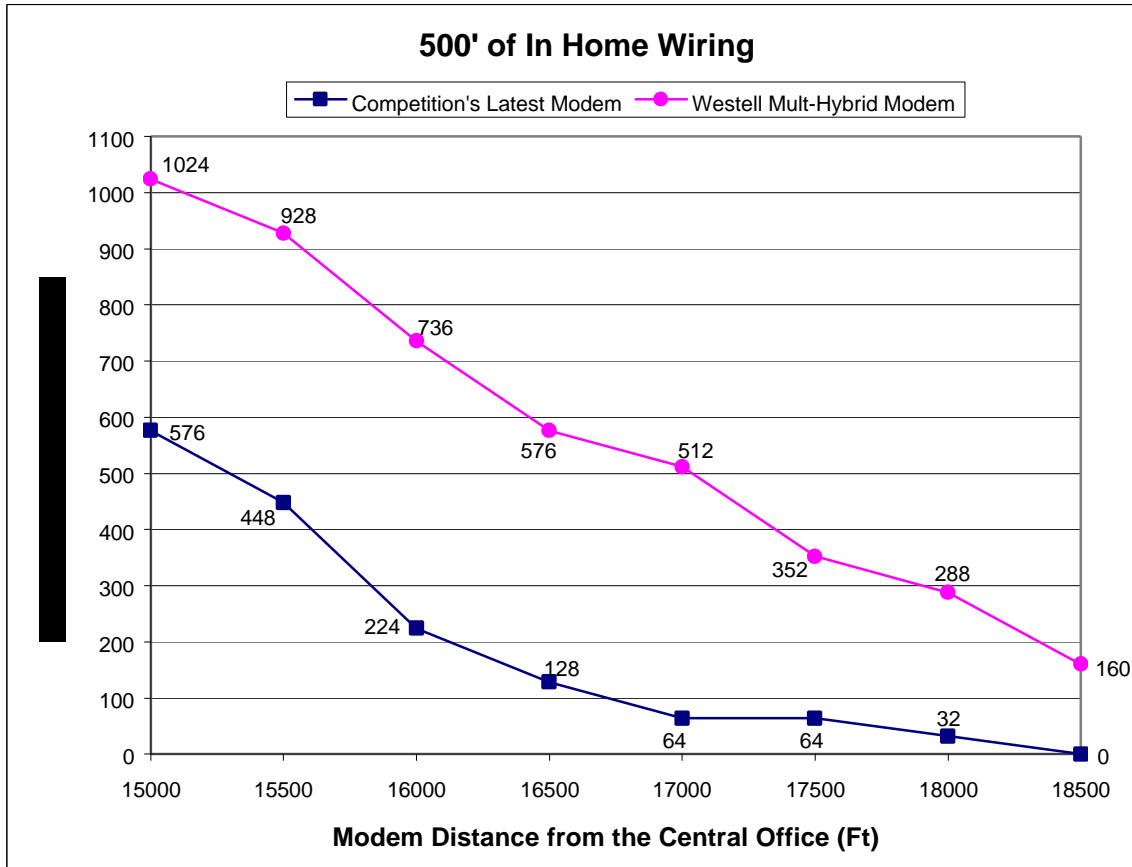
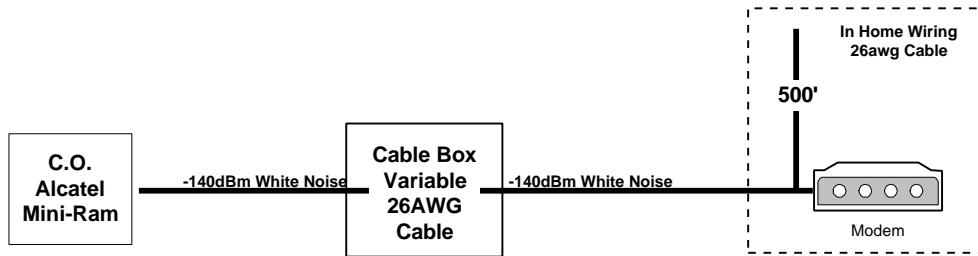
## Downstream

5 T1 AMI NEXT (-49.6) with -140dBm White Noise

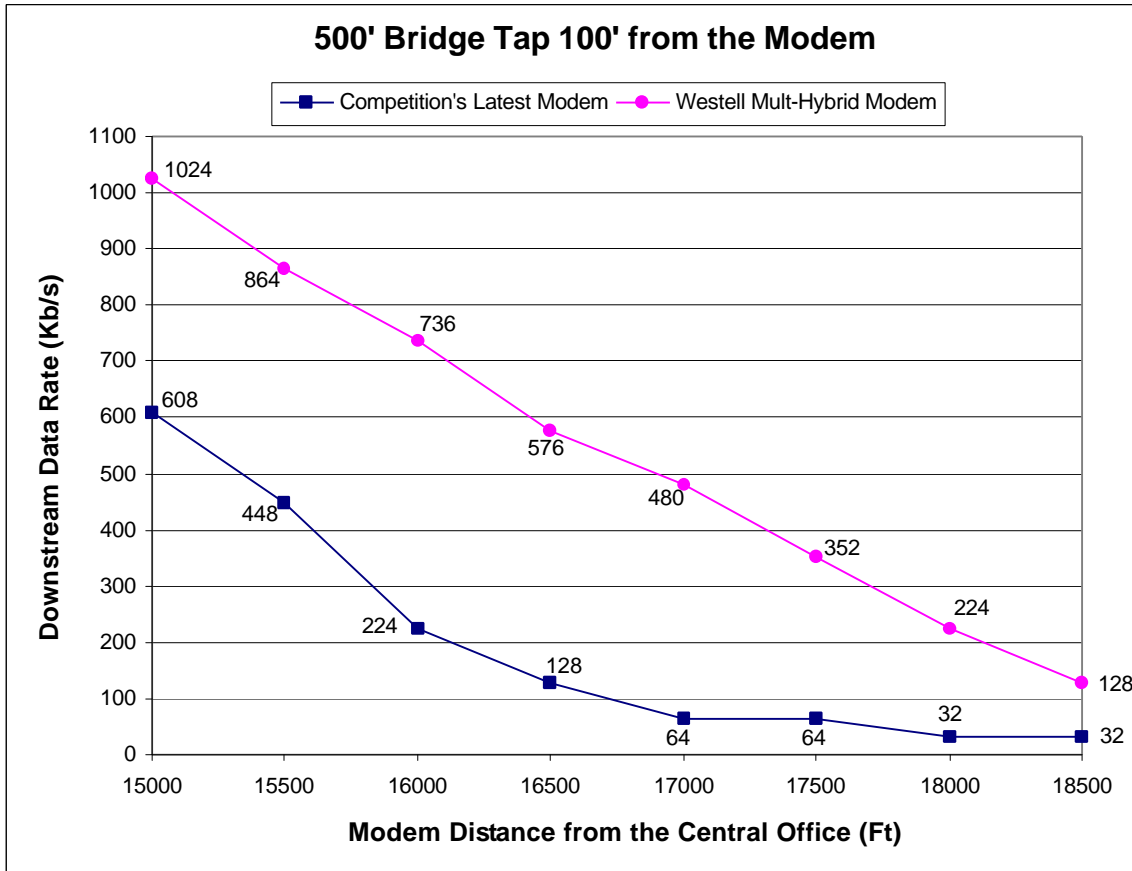
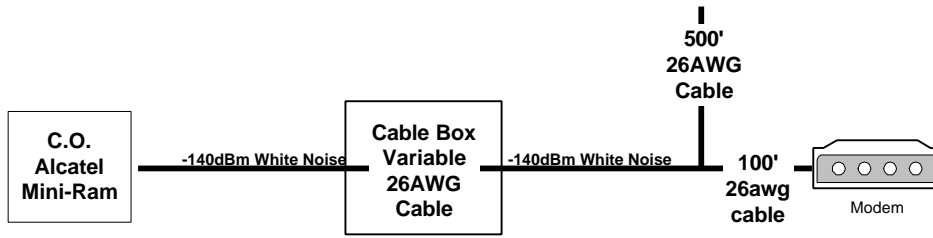




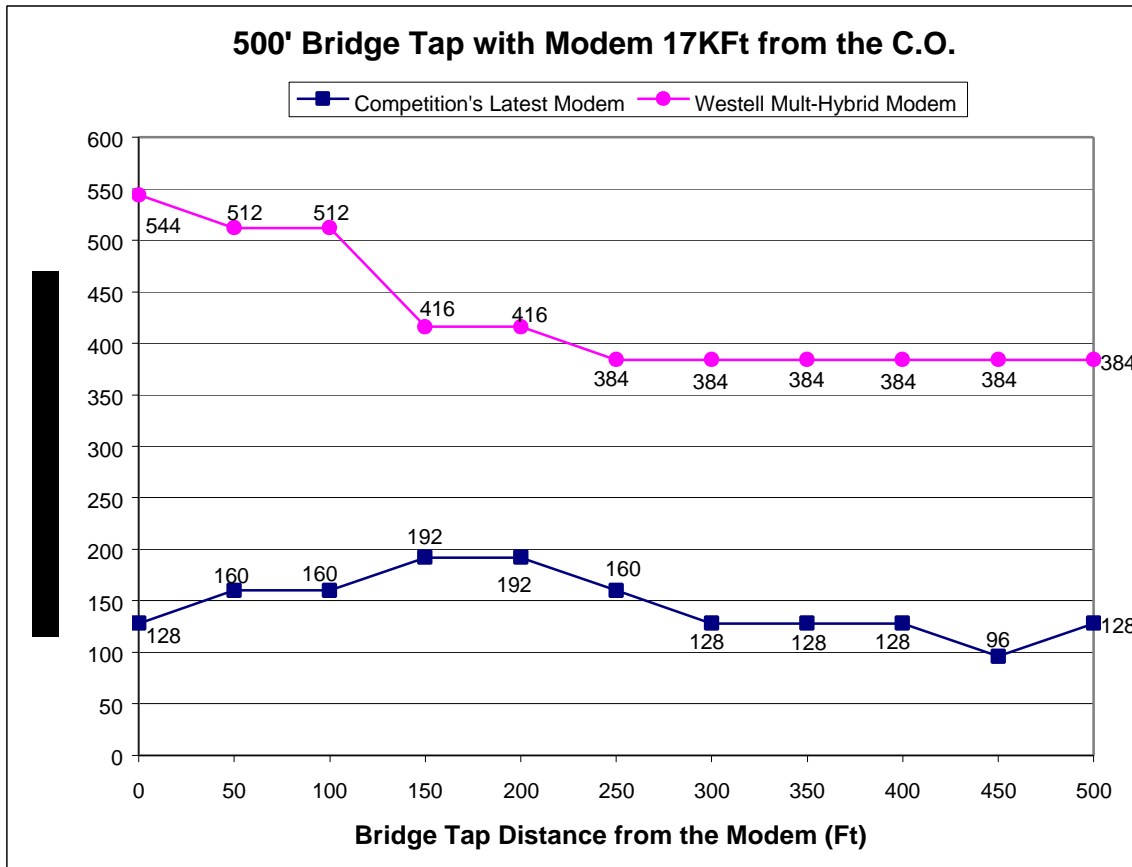
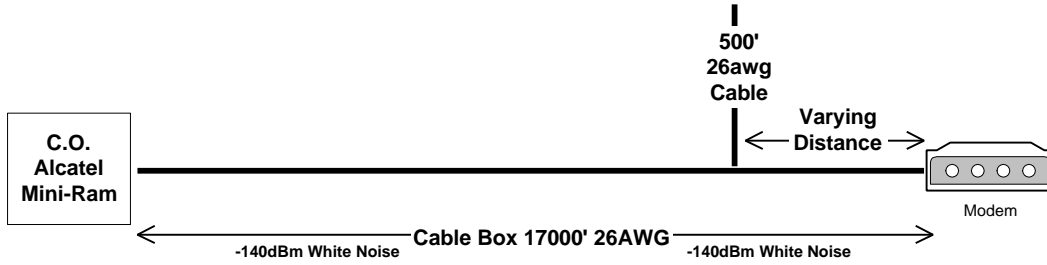
In Home Wiring with an External Bridge 500' Bridge Tap							
Modem Type	Distance from the Central Office (Ft)						
	15000'	15500'	16000'	16500'	17000'	17500'	18000'
	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up
Multi-Hybrid	928/288	768/224	672/192	544/160	384/128	288/96	224/64
Competition's Latest Modem	608/544	448/512	320/480	192/416	64/352	32/320	No Sync



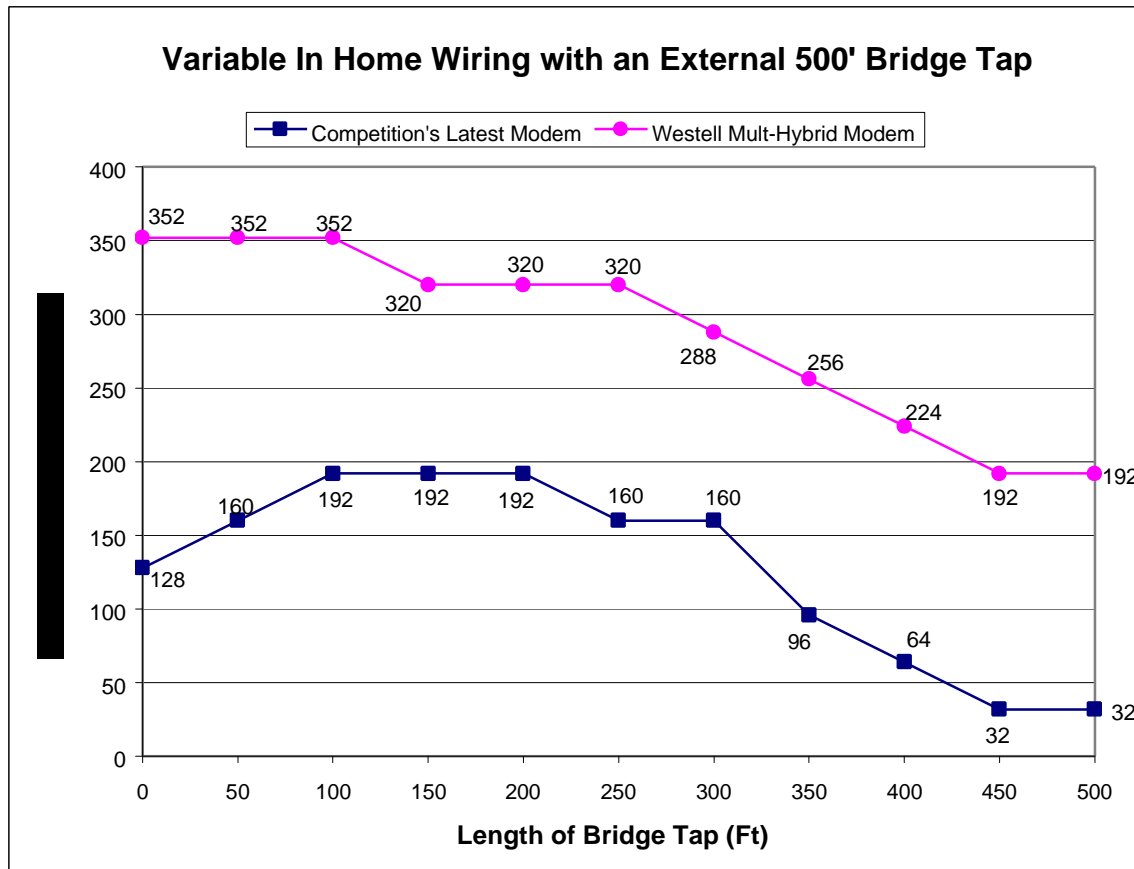
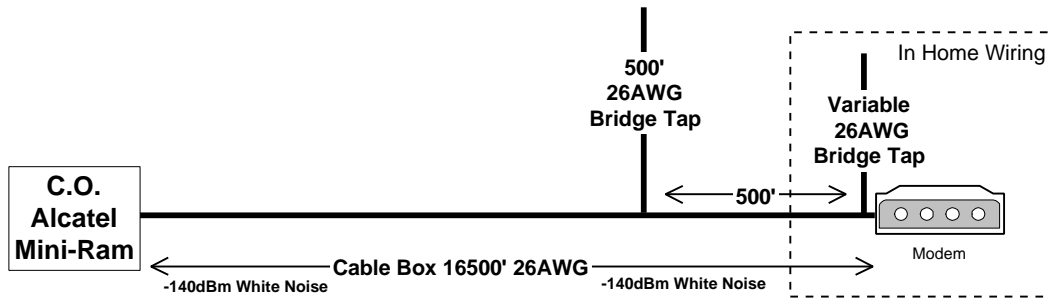
500' of In Home Wiring								
Modem Type	Distance from the Central Office (Ft)							
	15000'	15500'	16000'	16500'	17000'	17500'	18000'	18500'
	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up
Multi-Hybrid	1024/320	928/288	736/224	576/192	512/160	352/128	288/96	160/32
Competition's Latest Modem	576/608	448/544	224/512	128/448	64/416	64/320	32/288	No Sync



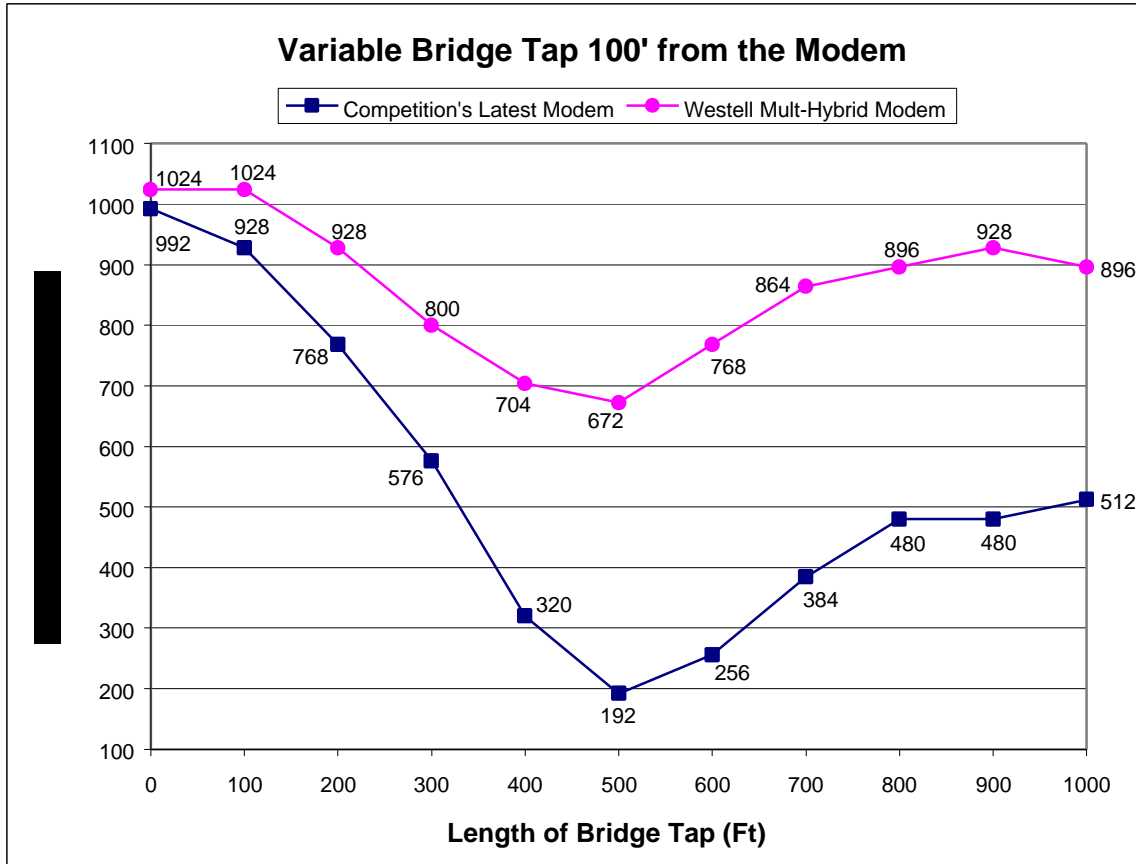
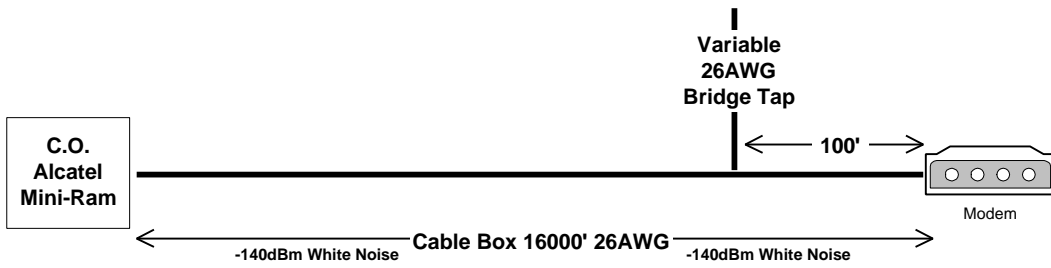
500' Bridge Tap 100' from the Modem								
Modem Type	Distance from the Central Office (Ft)							
	15000'	15500'	16000'	16500'	17000'	17500'	18000'	18500'
	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up
Multi-Hybrid	1024/320	864/256	736/224	576/192	480/160	352/128	224/96	128/32
Competition's Latest Modem	608/608	448/544	224/512	128/448	64/416	64/320	32/288	32/256



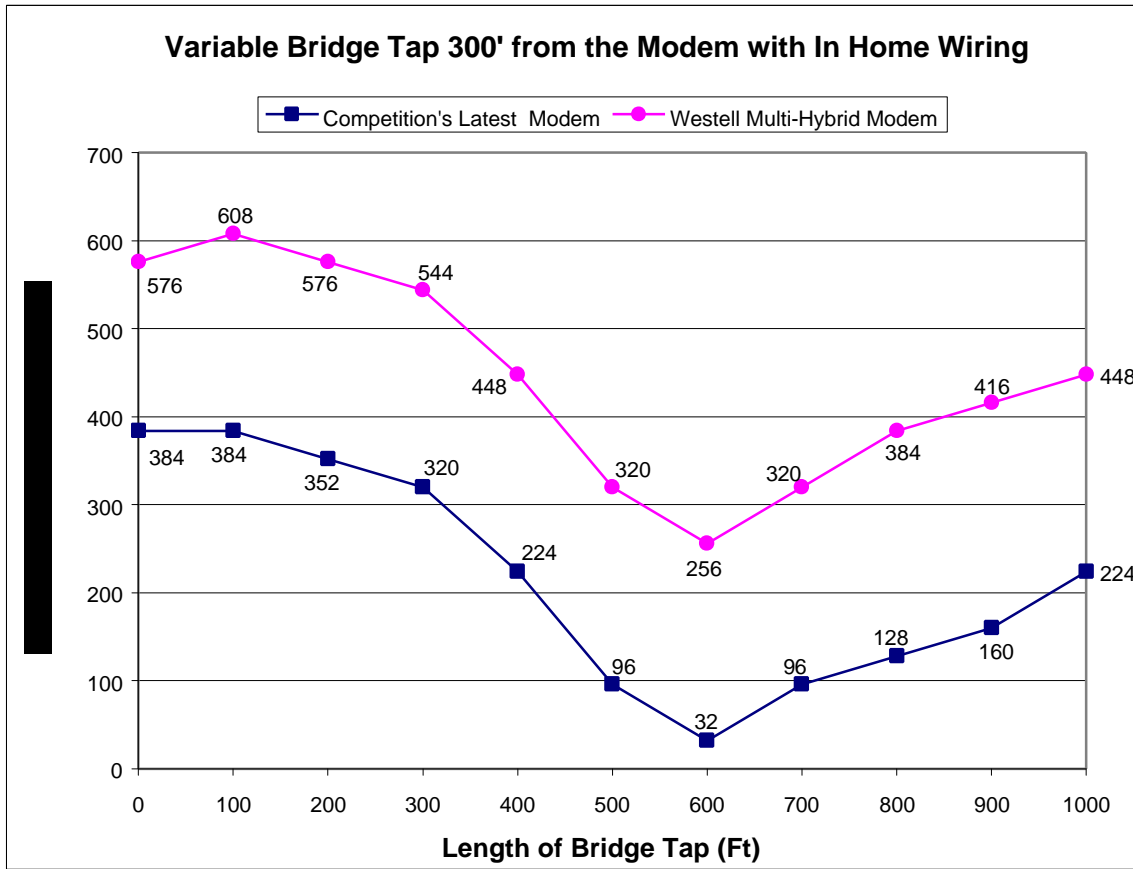
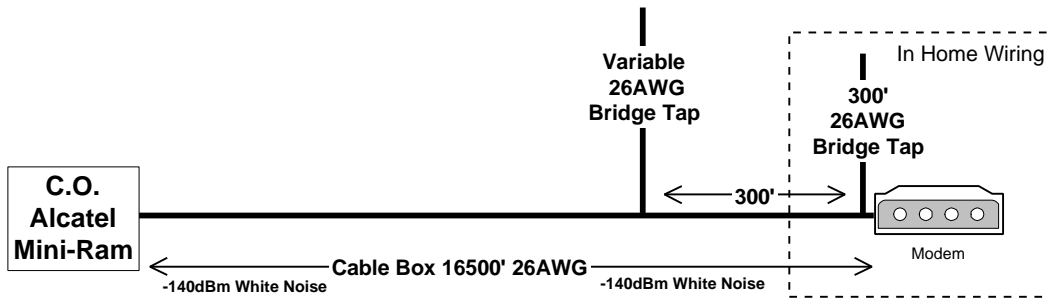
<b>500' Bridge Tap with Modem 17Kft from the C.O.</b>											
<b>Modem Type</b>	<b>Bridge Tap Distance from the Modem (Ft)</b>										
	0'	50'	100'	150'	200'	250'	300'	350'	400'	450'	500'
	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up
Multi-Hybrid	544/192	512/192	512/192	416/192	416/192	384/192	384/192	384/192	384/192	384/192	384/192
Competition's Latest Modem	128/448	160/416	160/448	192/416	192/416	160/416	128/416	128/416	128/448	96/448	128/448



Variable In Home Wiring with an External 500' Bridge Tap											
Modem Type	Length of Bridge Tap (Ft)										
	0'	50'	100'	150'	200'	250'	300'	350'	400'	450'	500'
	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up
Multi-Hybrid	352/192	352/192	352/192	320/192	320/192	320/192	288/192	256/160	224/160	192/192	192/160
Competition's Latest Modem	128/448	160/448	192/448	192/448	192/448	160/448	160/448	96/448	64/448	32/448	32/384

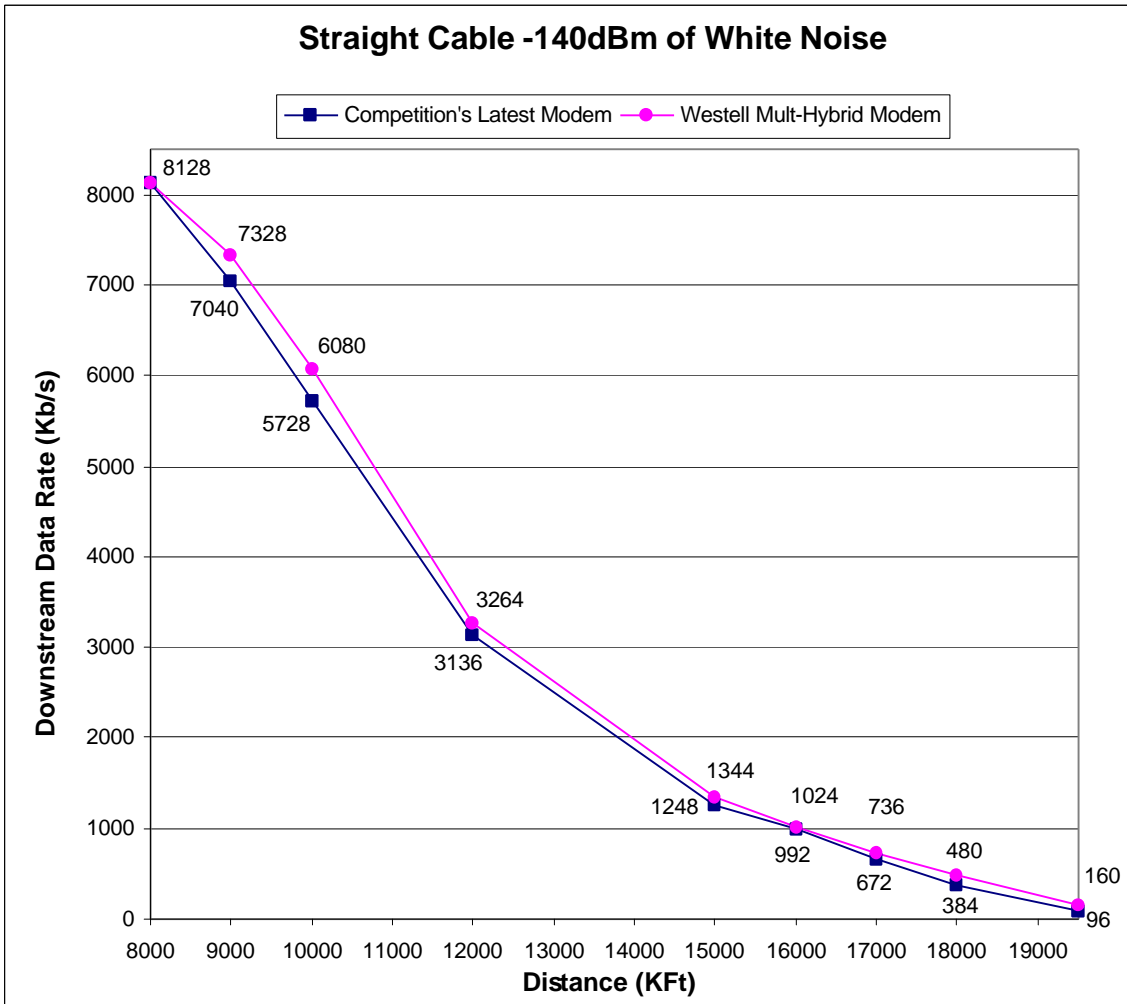
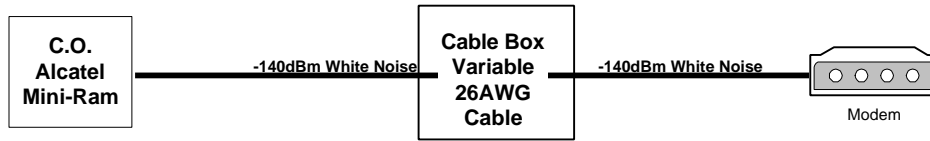


Variable Bridge Tap 100' from the Modem											
Modem Type	Length of Bridge Tap (Ft)										
	0'	100'	200'	300'	400'	500'	600'	700'	800'	900'	1000'
	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up
Multi-Hybrid	1024/256	1024/256	928/224	800/224	704/224	672/224	768/192	864/192	896/192	928/160	896/160
Competition's Latest Modem	992/544	928/512	768/512	576/512	320/480	192/480	256/480	384/448	480/448	480/416	512/416



**Variable Bridge Tap 300' from the Modem with In Home Wiring**

Modem Type	Length of Bridge Tap (Ft)										
	0'	100'	200'	300'	400'	500'	600'	700'	800'	900'	1000'
	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up
Multi-Hybrid	576/160	608/192	576/160	544/160	448/160	320/160	256/128	320/128	384/128	416/128	448/96
Competition's Latest Modem	384/448	384/448	352/416	320/416	224/416	96/416	32/416	96/384	128/384	160/352	224/352



<b>Straight Cable -140dBm of White Noise</b>									
<b>Modem Type</b>	<b>Distance of Modem from the C.O. (Ft)</b>								
	8000'	9000'	10000'	12000'	15000'	16000'	17000'	18000'	19500'
	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up	Down/Up
Multi-Hybrid	8128/1024	7328/1024	6080/960	3264/800	1344/544	1024/448	736/352	480/288	160/160
Competition's Latest Modem	8128/928	7040/928	5728/896	3136/832	1248/608	992/544	672/448	384/352	96/224