A Method for Accelerating File Transfers over Satellite Links

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October 25, 2004

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Introduction

Comtech EF Data's Performance Enhancement Proxy (PEP) products, the turboIP® and turboVR™, are designed to alleviate TCP/IP bottlenecks in an impaired environment (high delay, high bit error rate, or both), while preserving interoperability with any TCP device. It achieves this by combining TCP with a number of enhancements that modernize IP transport.

CEFD's PEP products, co-developed with Global Protocols, Inc., are based on SCPS-TP, the Transport Protocol of SCPS, an open standard specifically defined for space communications. This standard is open, published, and internationally distributed. SCPS-TP is an ISO standard (15893), a CCSDS standard (714.0-B-1), and a MIL-STD (MIL-STD-2045-44000).

CEFD's PEP products are fully compatible with network devices that use TCP, supporting existing Internet standards, including network congestion and retransmission schemes. This allows the PEP products at one end of the link to operate with TCP devices at the other end of the link without the need for a peer PEP device, providing partial performance enhancement. However, it is recommended that TCP traffic pass through a pair of PEP devices in order to take full advantage of the SCPS-TP protocol.

The key features of CEFD's PEP products that help alleviate TCP/IP performance bottlenecks are:

Quick Start	Takes full and immediate use of the links available, eliminating the inefficiencies of the TCP slow-start algorithm.
Window Scaling	Supports window sizes up to 1 Gbyte, far exceeding the standard TCP window size of 64 Kbytes.
Intelligent Congestion Control	Is optimized for real-world, mixed-loss environments. It is capable of distinguishing data corruption from congestion-induced data loss. Doing so prevents unnecessary activation of congestion control mechanisms, which can lead to significant reductions in transmission rates.
Rate Pacing	Meters out bursty traffic at a rate not to exceed the configured transmission rate of the satellite channel. This prevents the satellite channel from becoming congested.
Selective Negative Acknowledgments (SNACKs)	SNACKs identify specific lost or damaged packets and request retransmission of those packets. This provides for quicker recovery and better bandwidth utilization in lossy environments.

Purpose

The purpose of this white paper is to present the performance improvements that can be anticipated when CEFD's PEP products are incorporated. The two most commonly used TCP protocols in use today are File Transfer Protocol (FTP) and Hyper Text Transfer Protocol (HTTP). The focus of this paper is on the specific performance improvements provided by CEFD PEP devices when FTP is used across a satellite link.

FTP Performance Improvements

Comtech EF Data's PEP products greatly mitigate the effects of satellite delay and lossy links on data file transfers over a satellite when FTP is the transport protocol. Tables 1 and 2 summarize the typical performance improvements that can be anticipated when CEFD PEP devices are employed when performing an FTP Put and FTP Get over a single-hop satellite link.

Table 1 – PEP Improvement for FTP Put

	BER = 1.0 E-7	BER = 1.0 E-6	BER = 1.0 E-5
64000 bps link	**10%**	**10%**	**51%**
128000 bps link	**11%**	**17%**	**134%**
256000 bps link	**15%**	**31%**	**256%**
512000 bps link	**32%**	**142%**	**514%**
1024000 bps link	**85%**	**323%**	**806%**
2048000 bps link	**253%**	**723%**	**1969%**

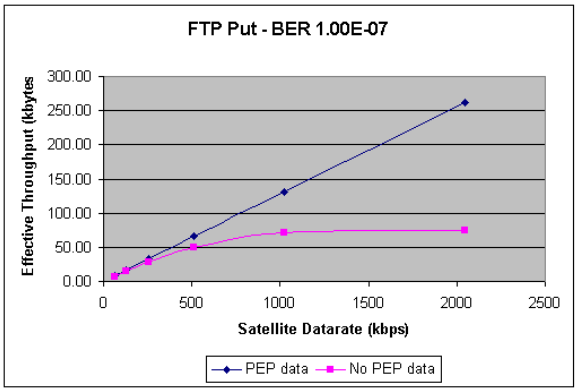
Table 2 – PEP Improvement for FTP Get

	BER = 1.0 E-7	BER = 1.0 E-6	BER = 1.0 E-5
64000 bps link	**18%**	**18%**	**85%**
128000 bps link	**34%**	**52%**	**247%**
256000 bps link	**71%**	**114%**	**441%**
512000 bps link	**148%**	**289%**	**825%**
1024000 bps link	**308%**	**725%**	**2156%**
2048000 bps link	**756%**	**1323%**	**2286%**

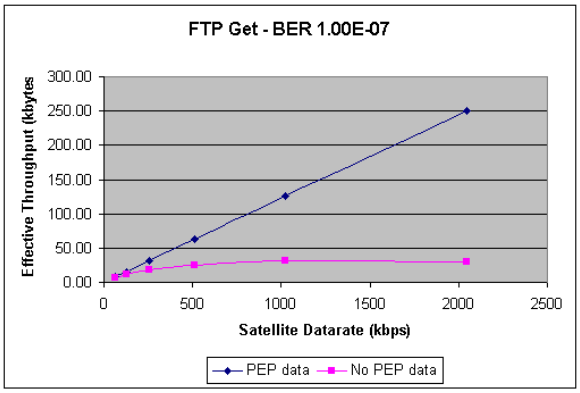
Graphs 1 through 6 on the next page very clearly display the effects of both delay and link Bit-Error-Rate on standard TCP traffic over a single-hop satellite link. As you can readily see, CEFD's PEP products greatly improve satellite bandwidth utilization when passing TCP traffic. The data presented in this white paper focuses on the performance advantages of the PEP products in a single-hop situation (i.e., Round Trip Time of ~500 milliseconds).

However, CEFD's PEP products do allow full satellite bandwidth utilization in both single-hop and double-hop environments. The performance of Standard TCP over a double-hop link is even more degraded than the results presented here for a single-hop link. Fortunately, the performance improvements described in this paper scale appropriately in double-hop scenarios.

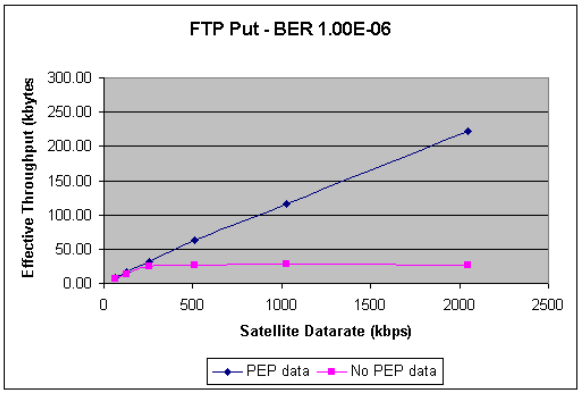
CEFD offers PEP products that support data rates of up to 15 Mbps. Please visit CEFD's website for datasheets and other information on this line of products.



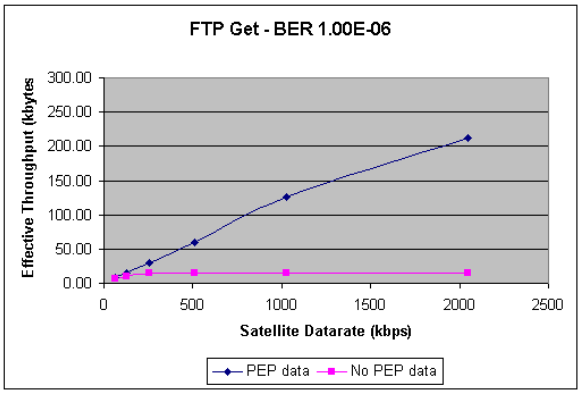
Graph 1 – PEP Improvement Put – 1.0E-7



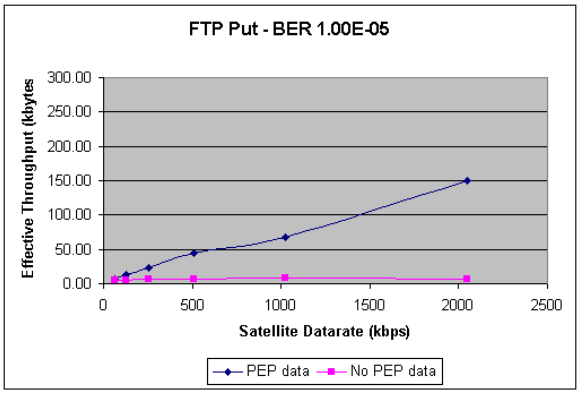
Graph 2 – PEP Improvement Put – 1.0E-7



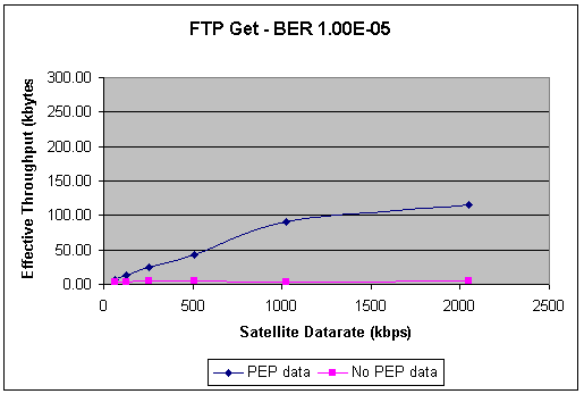
Graph 3 – PEP Improvement Put – 1.0E-6



Graph 4 – PEP Improvement Put – 1.0E-6



Graph 5 – PEP Improvement Put – 1.0E-5



Graph 6 – PEP Improvement Put – 1.0E-5

Configuration Details

Comtech EF Data's PEP products can be used for performance enhancement in any satellite link that is passing TCP/IP traffic. The PEP device can be used directly with CEFD's IP-enabled satellite modems as shown in Figure 1, or with the more traditional satellite modem / router configuration as depicted in Figure 2. The performance of the PEP device is similar in either configuration.

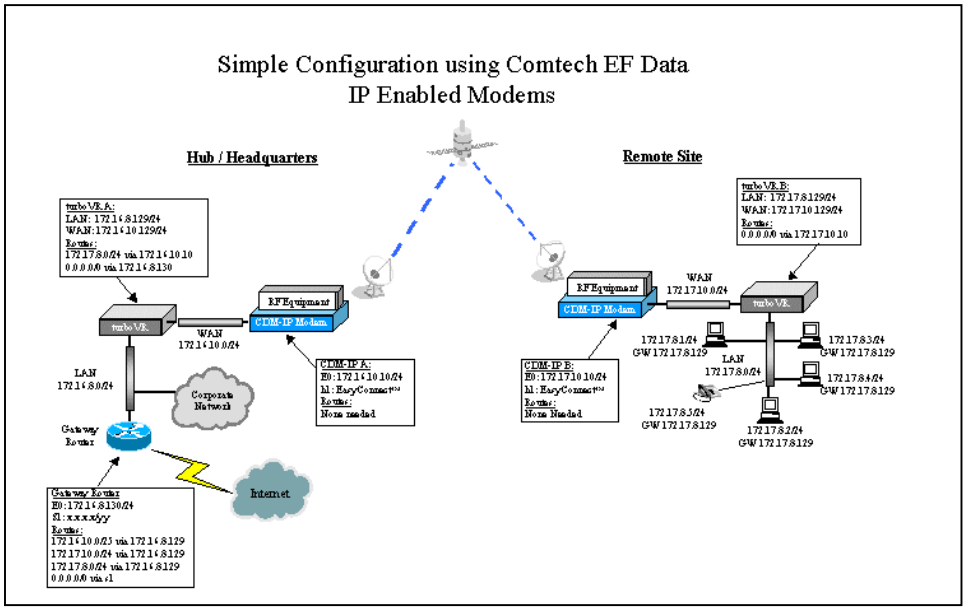


Figure 1 – PEP Devices with CEFD IP-Enabled Modems

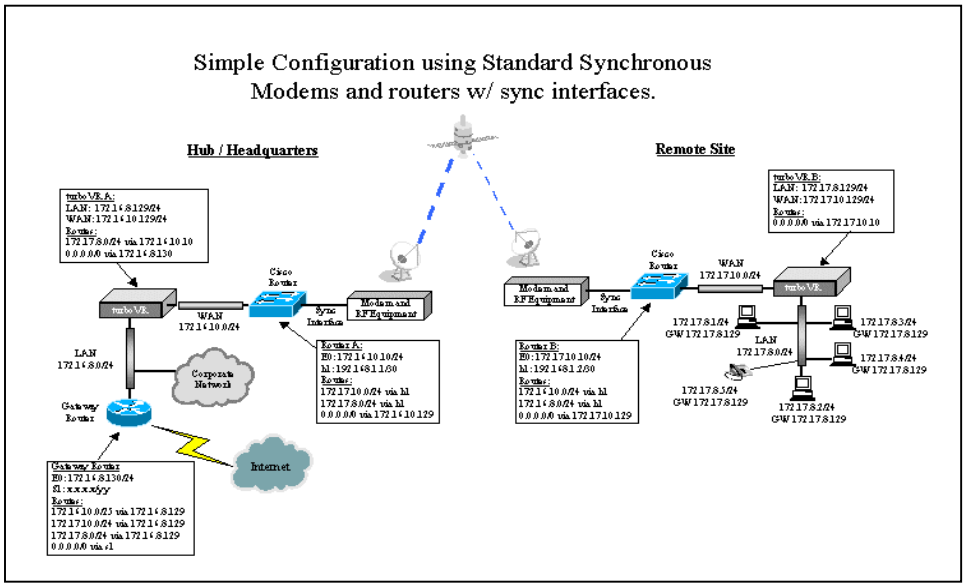


Figure 2 – PEP Devices with Standard Synchronous Modems

A brief discussion of the differences between an FTP Put and an FTP Get is warranted in order to fully understand the results presented in this paper.

FTP PUT AND GET TIME KEEPING

Another point of interest in evaluating FTP performance is how an FTP Client measures the file transfer time to calculate the effective throughput. For a Put, most Client applications start the timer after the initial Client/Server login authentication and port setup transactions have occurred. At this time, the first segment is immediately passed down the IP stack from the application. The timer is stopped when the last segment is passed down the stack. For a Get, the timer is started again after the Client/Server login authentication and port setup transactions have occurred. However, the timer is not stopped until the application layer receives the last segment. These differences mean that the reported time of a file transfer using FTP Put over a single or multiple satellite hops will be inaccurate. This inaccuracy will be equivalent to at least the round trip time of a packet over the link. The result is that for small file transfers, the reported throughput via the client application can exceed the actual available bandwidth of the satellite link. The reported transfer time / throughput for an FTP Get is actually a more accurate indication, especially when the file transfer includes single or multiple satellite hops.

FTP SERVER PERFORMANCE

Not all FTP servers are created equal, and the old adage “you get what you pay for” very much applies here. Many low cost (or even freeware), entry-level, home-user FTP servers are available. Almost all of the FTP servers in this class that have been tested by CEFD have the same performance characteristics: adequate Put performance and very reduced or totally inadequate Get performance. There are two common issues in FTP servers that fall into this ‘entry-level’ category. First, many of these products have relatively small, fixed transmit and receive buffers (32k bytes or less). Second, many of these servers set the ‘PUSH’ Flag of the TCP header when performing an FTP Get. This will have a large negative effect on the maximum FTP throughput that can be achieved. The PUSH flag being set causes the receiving IP stack to immediately pass the segment up the stack to the application layer. When the PUSH flag is not used, the IP stack will bring in all segments within the window before sending it up the IP stack to the application layer. The result is that when PUSH is implemented, acknowledgements from the receiver to the sender are significantly delayed and the TCP’s Slow Start algorithm never allows the pace of the ‘transactions’ to reach full speed. The Get performance of Servers in this class of product can vary widely. One product tested by CEFD could only achieve a maximum Get throughput of ~25k bytes/second over standard terrestrial connections (i.e., no satellite delay). Other products varied between ~50k and 75k bytes/second. **CEFD highly recommends that all customers benchmark their server performance by running simple tests via the locally attached network (i.e., no satellite delay) before testing the performance of our PEP products.**

THE TEST

The data presented in this white paper was taken using the test setup shown in Figure 3. The FTP Server used for this setup was WS_FTP Server Manager, Version 5.0.0 from Ipswitch.

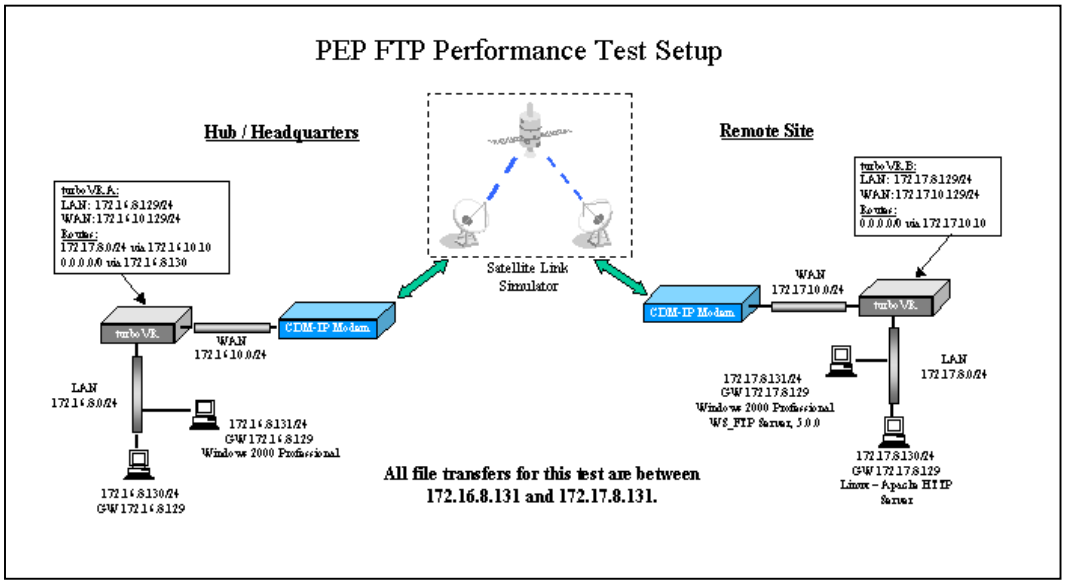


Figure 3 – PEP FTP Performance Test Setup

TEST DATA

Tables 3 through 8 provide the test data taking using the test setup shown previously in Figure 1.

Windows 2000 Professional, WS_FTP Server Version 5.0.0
Satellite Link - Viterbi 7/8 QPSK, 64kbps, RTT ~ 540 milliseconds
Data File - 5,242,895 bytes (41,943,160 bits)

BER	With PEP Product		Without PEP		With PEP Product		Without PEP	
	Put Time (seconds)	Put Throughput (kbytes/second)	Put Time (seconds)	Put Throughput (kbytes/second)	Get Time (seconds)	Get Throughput (kbytes/second)	Get Time (seconds)	Get Throughput (kbytes/second)
1.00E-07	639.37	8.20	698.12	7.51	675.63	7.76	788.41	6.65
	639.37	8.20	699.99	7.49	674.75	7.77	788.41	6.65
	638.63	8.21	697.19	7.52	674.75	7.77	812.85	6.45
	637.16	8.23	728.18	7.20	674.75	7.77	784.86	6.68
Average	**638.64**	**8.21**	**705.87**	**7.43**	**674.97**	**7.77**	**793.63**	**6.61**
		PEP Performance	**110%**			**PEP Performance**	**118%**	
1.00E-06	647.62	8.10	702.80	7.46	678.29	7.73	793.18	6.61
	646.10	8.11	707.54	7.41	681.88	7.69	806.60	6.50
	648.38	8.09	725.16	7.23	677.40	7.74	786.04	6.67
	641.60	8.17	708.50	7.40	683.68	7.67	838.86	6.25
Average	**645.93**	**8.12**	**711.00**	**7.38**	**680.32**	**7.71**	**806.17**	**6.51**
		PEP Performance	**110%**			**PEP Performance**	**118%**	
1.00E-05	749.55	6.99	1069.98	4.90	771.57	6.80	1314.01	3.99
	717.43	7.31	1183.50	4.43	779.73	6.72	1593.59	3.29
	738.53	7.10	1072.17	4.89	784.47	6.68	1444.32	3.63
	737.54	7.11	1117.89	4.69	797.81	6.57	1481.04	3.54
Average	**735.76**	**7.13**	**1110.88**	**4.73**	**783.40**	**6.69**	**1944.32**	**3.61**
		PEP Performance	**151%**			**PEP Performance**	**185%**	

Figure 3 – PEP Performance Improvement Data – 64000 bps

Windows 2000 Professional, WS_FTP Server Version 5.0.0
Satellite Link - Viterbi 7/8 QPSK, 128kbps, RTT ~ 540 milliseconds
Data File - 5,242,895 bytes (41,943,160 bits)

BER	With PEP Product		Without PEP		With PEP Product		Without PEP	
	Put Time (seconds)	Put Throughput (kbytes/second)	Put Time (seconds)	Put Throughput (kbytes/second)	Get Time (seconds)	Get Throughput (kbytes/second)	Get Time (seconds)	Get Throughput (kbytes/second)
1.00E-07	317.58	16.51	350.93	14.94	334.37	15.68	448.88	11.68
	319.44	16.41	350.93	14.94	334.37	15.68	445.82	11.76
	318.14	16.48	354.97	14.77	334.37	15.68	450.03	11.65
	317.58	16.51	350.93	14.94	334.37	15.68	451.58	11.61
Average	**318.19**	**16.48**	**351.94**	**14.90**	**334.37**	**15.68**	**449.08**	**11.68**
		PEP Performance	**111%**			**PEP Performance**	**134%**	
1.00E-06	321.32	16.32	370.26	14.16	334.37	15.68	529.59	9.90
	323.99	16.18	367.41	14.27	335.03	15.65	494.61	10.60
	325.73	16.10	384.66	13.63	334.37	15.68	481.88	10.88
	322.46	16.26	395.99	13.24	335.91	15.61	539.39	9.72
Average	**323.38**	**16.21**	**379.58**	**13.83**	**334.92**	**15.65**	**511.37**	**10.28**
		PEP Performance	**117%**			**PEP Performance**	**152%**	
1.00E-05	395.60	13.25	890.13	5.89	391.12	13.40	1497.97	3.50
	383.10	13.69	911.81	5.75	372.52	14.07	1379.71	3.80
	390.22	13.44	856.68	6.12	408.70	12.83	1263.35	4.15
	394.17	13.30	1004.39	5.22	382.60	13.70	1269.47	4.13
Average	**390.77**	**13.42**	**915.75**	**5.75**	**388.74**	**13.50**	**1803.50**	**3.90**
		PEP Performance	**234%**			**PEP Performance**	**347%**	

Figure 4 – PEP Performance Improvement Data – 128000 bps

Windows 2000 Professional, WS_FTP Server Version 5.0.0
Satellite Link - Viterbi 7/8 QPSK, 256kbps, RTT ~ 540 milliseconds
Data File - 5,242,895 bytes (41,943,160 bits)

BER	With PEP Product		Without PEP		With PEP Product		Without PEP	
	Put Time (seconds)	Put Throughput (kbytes/second)	Put Time (seconds)	Put Throughput (kbytes/second)	Get Time (seconds)	Get Throughput (kbytes/second)	Get Time (seconds)	Get Throughput (kbytes/second)
1.00E-07	161.59	32.45	182.87	28.67	167.93	31.22	284.01	18.46
	160.06	32.76	182.81	28.68	168.21	31.17	289.18	18.13
	160.63	32.64	187.05	28.03	167.99	31.21	287.28	18.25
	160.25	32.72	183.77	28.53	168.04	31.20	286.03	18.33
Average	**160.63**	**32.64**	**184.12**	**28.48**	**168.04**	**31.20**	**286.63**	**18.29**
		PEP Performance	**115%**			**PEP Performance**	**171%**	
1.00E-06	164.55	31.86	189.69	27.64	170.76	30.70	345.61	15.17
	166.99	31.40	255.50	20.52	180.30	29.08	409.60	12.80
	164.15	31.94	194.61	26.94	168.21	31.17	394.50	13.29
	165.92	31.60	242.39	21.63	167.82	31.24	328.30	15.97
Average	**165.40**	**31.70**	**220.55**	**24.18**	**171.77**	**30.55**	**369.50**	**14.31**
		PEP Performance	**131%**			**PEP Performance**	**214%**	
1.00E-05	213.30	24.58	754.37	6.95	223.58	23.45	1067.80	4.91
	229.85	22.81	798.01	6.57	215.32	24.35	1183.50	4.43
	251.62	20.84	916.59	5.72	224.58	23.35	1372.49	3.82
	248.26	21.12	894.69	5.86	202.33	25.91	1099.14	4.77
Average	**235.76**	**22.34**	**840.92**	**6.28**	**216.45**	**24.26**	**1180.73**	**4.48**
		PEP Performance	**356%**			**PEP Performance**	**541%**	

Figure 5 – PEP Performance Improvement Data – 256000 bps

Windows 2000 Professional, WS_FTP Server Version 5.0.0
Satellite Link - Viterbi 7/8 QPSK, 512kbps, RTT ~ 540 milliseconds
Data File - 5,242,895 bytes (41,943,160 bits)

BER	With PEP Product		Without PEP		With PEP Product		Without PEP	
	Put Time (seconds)	Put Throughput (kbytes/second)	Put Time (seconds)	Put Throughput (kbytes/second)	Get Time (seconds)	Get Throughput (kbytes/second)	Get Time (seconds)	Get Throughput (kbytes/second)
1.00E-07	79.66	65.81	103.90	50.46	83.52	62.77	204.88	25.59
	80.55	65.09	113.29	46.28	83.59	62.72	204.88	25.59
	79.74	65.75	103.43	50.69	83.66	62.67	205.52	25.51
	79.74	65.75	101.80	51.50	83.59	62.72	213.56	24.55
Average	**79.93**	**65.60**	**105.61**	**49.73**	**83.59**	**62.72**	**207.21**	**25.31**
		PEP Performance	**132%**			**PEP Performance**	**248%**	
1.00E-06	81.20	64.57	248.48	21.10	83.59	62.72	322.64	16.25
	84.90	61.76	167.40	31.32	83.65	62.68	343.57	15.26
	82.25	63.75	157.40	33.31	83.52	62.77	397.19	13.20
	81.76	64.12	269.28	19.47	100.99	51.91	307.68	17.04
Average	**82.53**	**63.55**	**210.64**	**26.30**	**87.94**	**60.02**	**342.77**	**15.44**
		PEP Performance	**242%**			**PEP Performance**	**389%**	
1.00E-05	112.98	46.41	624.90	8.39	123.43	42.48	1167.68	4.49
	126.18	41.55	802.89	6.53	145.67	35.99	1090.00	4.81
	118.22	44.35	734.30	7.14	115.16	45.53	1132.37	4.63
	123.44	42.47	820.48	6.39	109.49	47.88	1125.08	4.66
Average	**120.20**	**43.70**	**745.64**	**7.11**	**123.44**	**42.97**	**1128.79**	**4.65**
		PEP Performance	**614%**			**PEP Performance**	**925%**	

Figure 6 – PEP Performance Improvement Data – 512000 bps

Windows 2000 Professional, WS_FTP Server Version 5.0.0
Satellite Link - Viterbi 7/8 QPSK, 1024kbps, RTT ~ 540 milliseconds
Data File - 5,242,895 bytes (41,943,160 bits)

BER	With PEP Product		Without PEP		With PEP Product		Without PEP	
	Put Time (seconds)	Put Throughput (kbytes/second)	Put Time (seconds)	Put Throughput (kbytes/second)	Get Time (seconds)	Get Throughput (kbytes/second)	Get Time (seconds)	Get Throughput (kbytes/second)
1.00E-07	39.54	132.59	92.89	56.44	41.80	125.43	166.97	31.40
	40.72	128.75	66.10	79.32	41.86	125.26	172.80	30.34
	39.46	132.86	78.59	66.71	41.73	125.63	174.07	30.12
	40.95	128.03	65.78	79.70	41.80	125.43	168.42	31.13
Average	**40.17**	**130.55**	**75.84**	**70.54**	**41.80**	**125.44**	**170.57**	**30.75**
		PEP Performance	**185%**			**PEP Performance**	**408%**	
1.00E-06	42.53	123.26	199.73	26.25	41.74	125.62	386.64	13.56
	48.26	108.64	216.92	24.17	41.74	125.62	302.88	17.31
	39.86	131.54	172.24	30.44	41.74	125.62	270.95	19.35
	50.93	102.95	177.67	29.51	41.80	125.44	492.29	10.65
Average	**45.39**	**116.60**	**191.64**	**27.59**	**41.75**	**125.58**	**363.19**	**15.22**
		PEP Performance	**423%**			**PEP Performance**	**825%**	
1.00E-05	74.91	69.99	795.58	6.59	50.28	104.28	1167.68	4.49
	60.14	87.18	614.64	8.53	62.02	84.53	1551.15	3.38
	87.26	60.09	784.86	6.68	63.11	83.07	1379.71	3.80
	98.11	53.44	649.68	8.07	56.27	93.17	1162.50	4.51
Average	**80.11**	**67.67**	**711.19**	**7.47**	**57.92**	**91.26**	**1315.26**	**4.05**
		PEP Performance	**906%**			**PEP Performance**	**2256%**	

Figure 7 – PEP Performance Improvement Data – 1024000 bps

Windows 2000 Professional, WS_FTP Server Version 5.0.0
Satellite Link - Viterbi 7/8 QPSK, 2048kbps, RTT ~ 540 milliseconds
Data File - 5,242,895 bytes (41,943,160 bits)

BER	With PEP Product		Without PEP		With PEP Product		Without PEP	
	Put Time (seconds)	Put Throughput (kbytes/second)	Put Time (seconds)	Put Throughput (kbytes/second)	Get Time (seconds)	Get Throughput (kbytes/second)	Get Time (seconds)	Get Throughput (kbytes/second)
1.00E-07	19.62	267.24	76.65	68.40	20.88	251.14	191.91	27.32
	19.62	267.24	64.61	81.15	20.95	250.22	153.44	34.17
	21.15	247.87	80.15	65.41	20.88	251.08	235.11	22.30
	19.62	267.24	63.59	82.45	20.88	251.08	156.55	33.49
Average	**20.00**	**262.40**	**71.25**	**74.35**	**20.90**	**250.88**	**184.25**	**29.32**
		PEP Performance	**353%**			**PEP Performance**	**856%**	
1.00E-06	19.62	267.24	171.22	30.62	29.53	177.57	352.82	14.86
	22.93	228.60	218.91	23.95	30.37	172.63	374.23	14.01
	22.85	229.46	193.46	27.10	20.88	251.08	340.45	15.40
	32.53	161.17	201.65	26.00	20.95	250.27	336.95	15.56
Average	**24.48**	**221.62**	**196.31**	**26.92**	**25.43**	**212.89**	**351.11**	**14.96**
		PEP Performance	**823%**			**PEP Performance**	**1423%**	
1.00E-05	62.43	83.98	707.54	7.41	55.40	94.63	994.86	5.27
	32.28	162.42	675.63	7.76	52.23	100.38	1134.83	4.62
	39.58	132.47	748.99	7.00	35.93	145.93	1157.37	4.53
	23.78	220.45	771.01	6.80	42.74	122.66	1046.49	5.01
Average	**39.52**	**149.83**	**725.79**	**7.24**	**46.58**	**115.90**	**1083.39**	**4.86**
		PEP Performance	**2069%**			**PEP Performance**	**2386%**	

Figure 8 – PEP Performance Improvement Data – 2048000 bps