

100 Mbps symmetric with Vectored DMT VDSL

July 2002 – IEEE 802.3ah EFM Meeting
Vancouver, Canada

J. Cioffi, G. Ginis, and K.B. Song

Stanford University

Cioffi@stanford.edu

J. Chow

Jubilant Communications

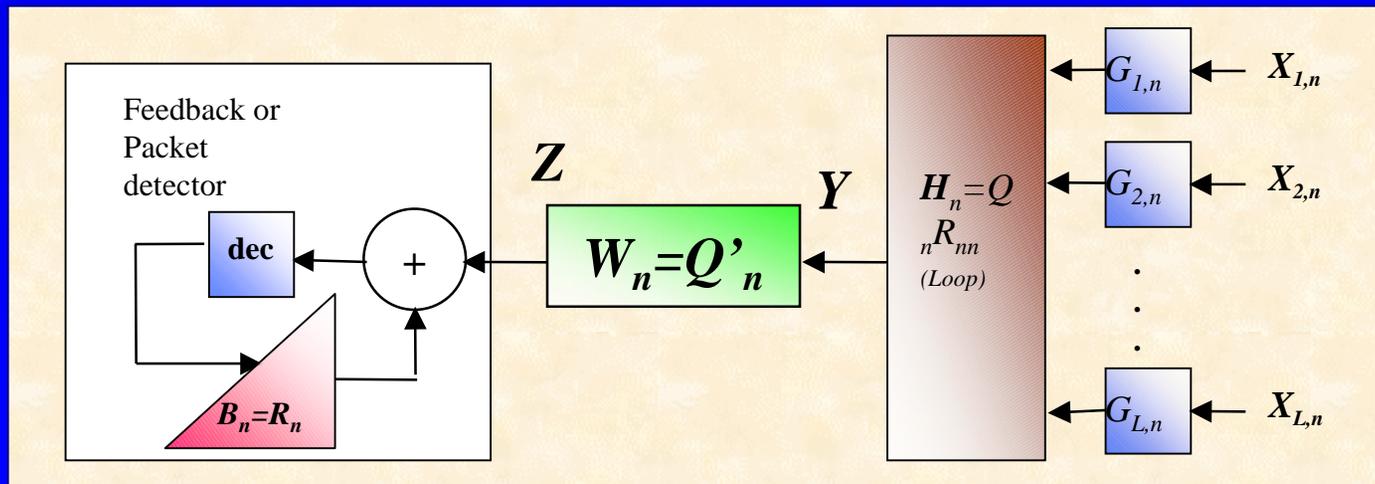
Jacky@jubilant.com

Vectored

Vectoring

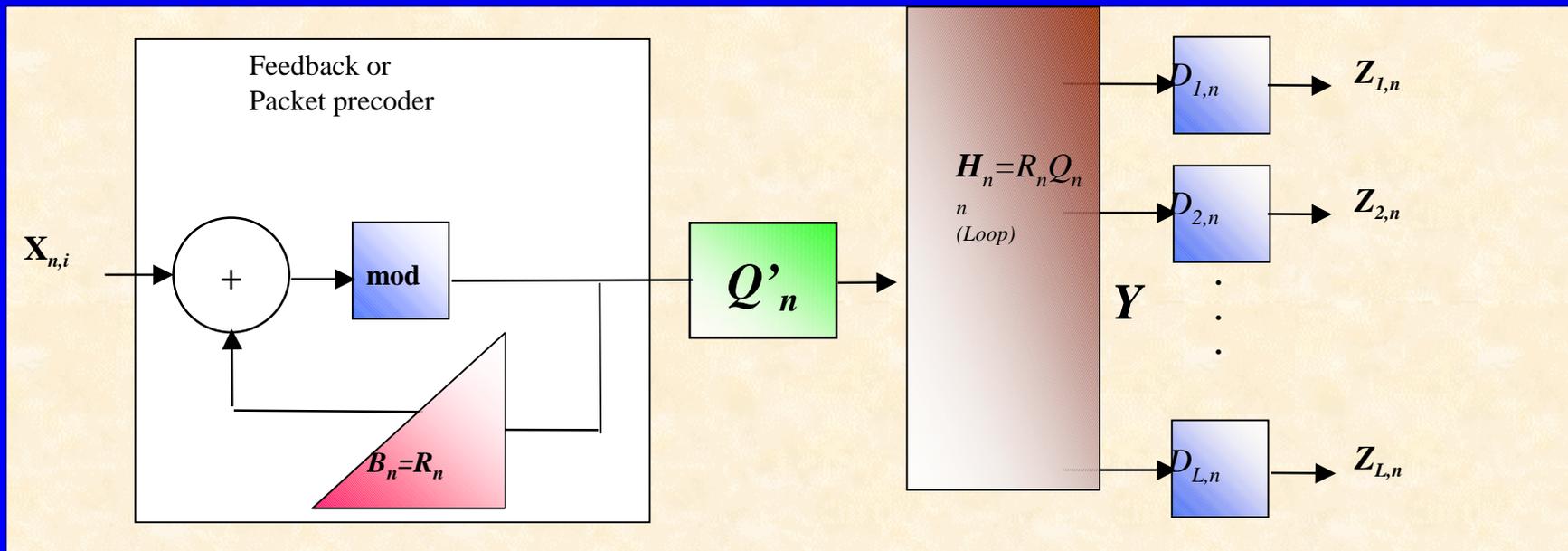
- Coordination on One Side
 - ◆ ONU or DSLAM
 - ◆ Downstream – co-generation of xmit signals
 - ◆ Upstream – co-reception of rcvr signals
- Highest possible data rates for all lines in binder
 - ◆ One-sided version of “vector OFDM” in 802.16 standard
- Independent of IW
 - ◆ Works for any spectra
 - ◆ Iterative water-fill is still optimum spectra
- Complexity – modest (25 to 50% of the FFT per line, only at DSLAM side, for example, in DMT)
 - ◆ No increase at client side of line

Upstream – Multiple Access (per tone)



- B, W can be 2×2 to 4×4 ($L=2$ or 4 in diagram above) matrices per tone, depending on crosstalk.
 - ◆ Exploits frequency-selective nature of actual crosstalk, which must be measured and then known at ONU
- Channel matrix H is factored by well-known QR factorization upon initialization
 - ◆ “Givens Rotations”
 - ◆ Easy to implement

Downstream Broadcast (per tone)

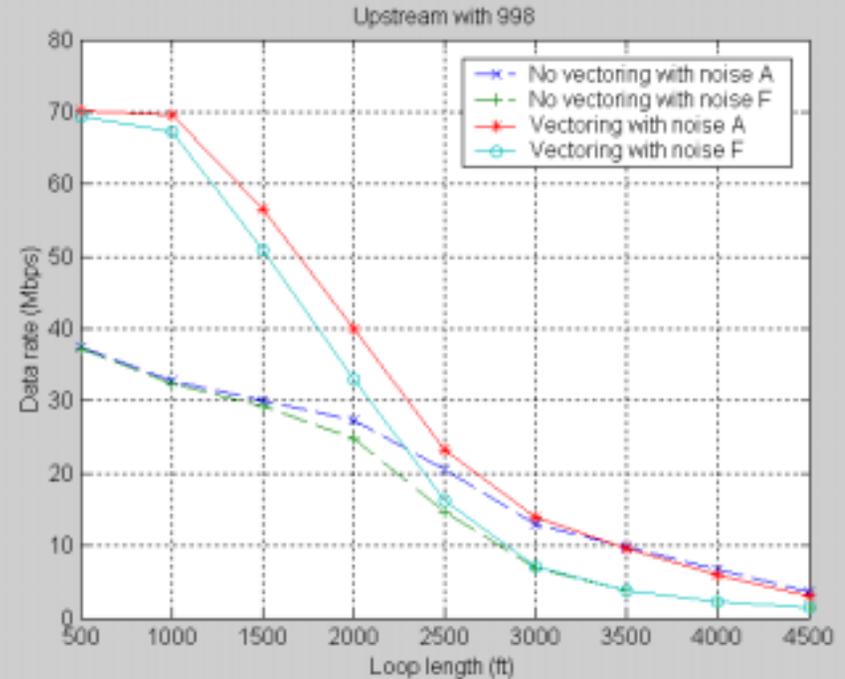
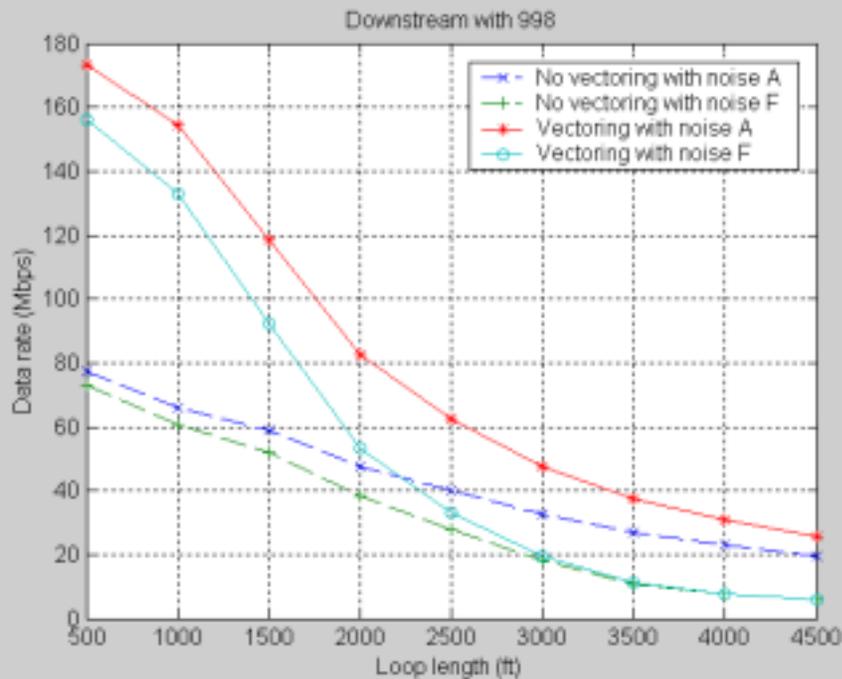


- Precoder similar to Tomlinson, but in “line domain”
- Also vector rotation on input to channel, again found by QR-factorization upon initialization

Complexity

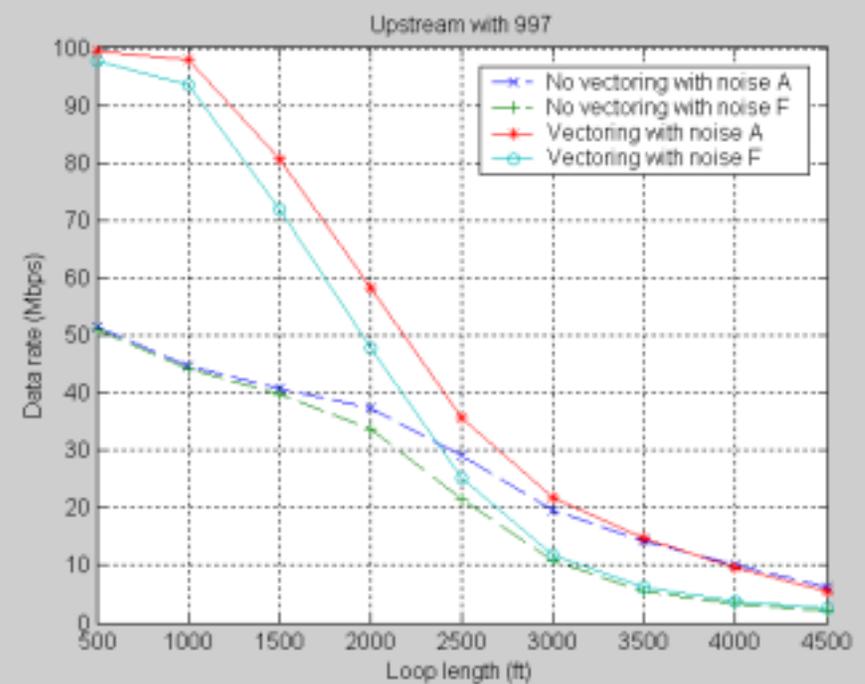
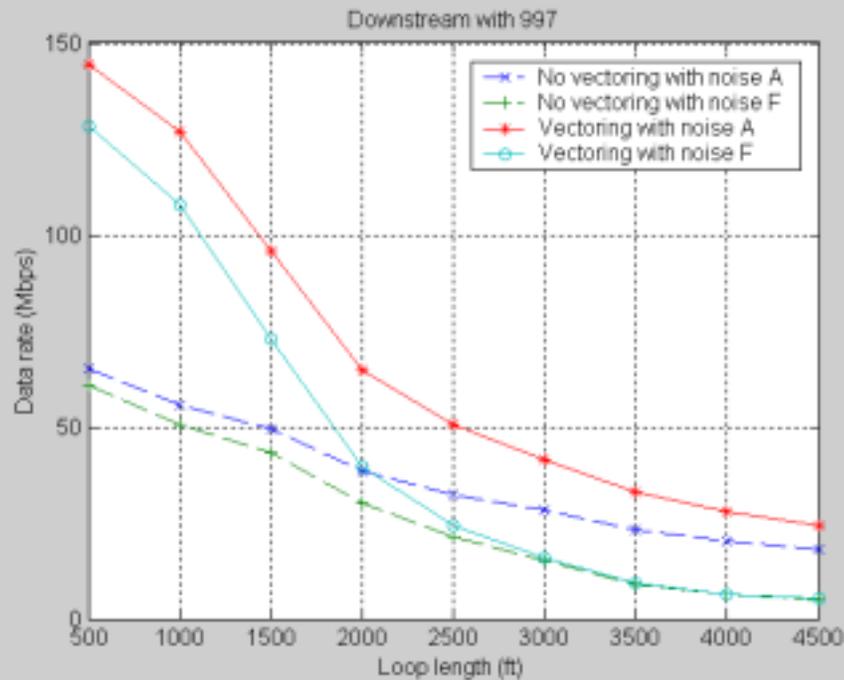
- FFT/IFFT and encoder/decoder the same.
- Add a matrix (2x2 to 4x4) for groups of 2 (or 4) users per tone
 - ◆ Linear increase per tone (close to 25 to 50% of the FFT per tone)
- Determination of H, initialization, training, etc, require augmentation with respect to existing systems
- Much need not be standardized, as this can be proprietary advantage of ONU/DSLAM vendors
- Better AFE leads to better performance

998 with/without Vectoring



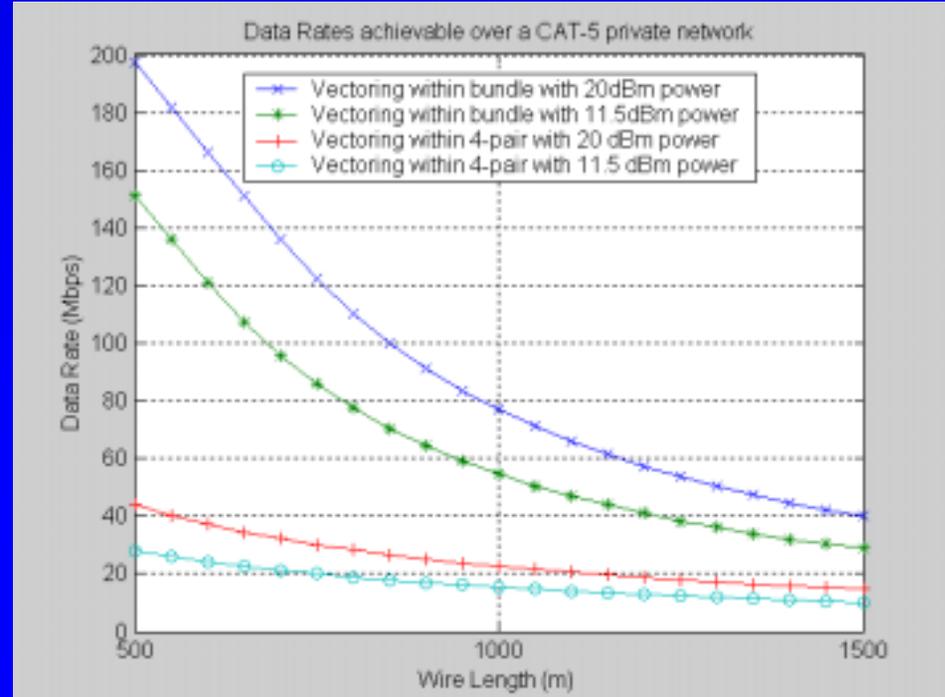
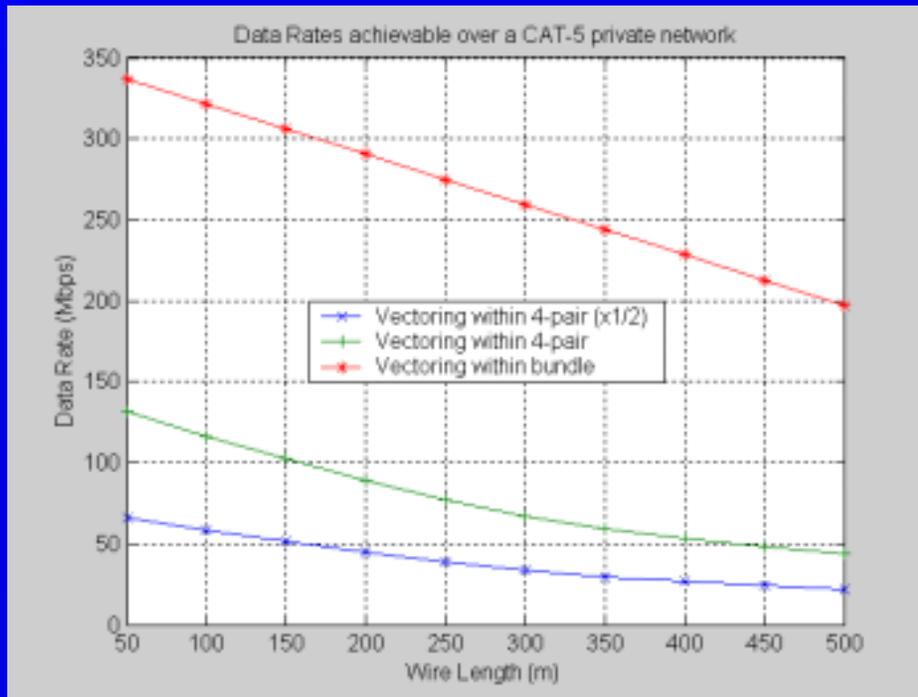
- Enormous gain, especially upstream at shorter lengths where FEXT is large
- Note IW spectra not used here

997 with/without Vectoring



- Little better symmetry, but downstream still larger

With IW and sum up/down rates



- Private network, either all lines or 4 of lines
 - ◆ If only 4, rest are uncoordinated
- 100 Mbps range
 - ◆ 1 km on 2 lines
 - ◆ >1.5 km on 4 lines
- Even when partially vectored, 100 Mbps on 2 lines at 500 m, 1 km on 4 lines

Vectored

100 Mbps Rates/Conclusions

Bit rate	# of lines	Rate/line	Range
100 Mbps	1	100 M	1000'
100 Mbps	2	50 M	3000'
100 Mbps	4	25 M	4500'

- EFM wants high-speed
- Enables G and 10G ethernet elsewhere
- Achieve >100 Mbps on a Single pair **Category 3 (26-gauge)** wire at 300 m
 - ◆ Achieve >100 Mbps on 4-pair Category 5 wires at 2 km

Motion:

- Add the following Objective Statement for IEEE 802.3ah Copper Track:
(in line with Ethernet speed: 10/100/1000)
- PHY for single pair non-loaded voice grade copper distance $\geq 300\text{m}$ and speed $\geq 100\text{ Mbps}$ full duplex