Optimizing STANAG 5066 Parameter Settings for HF & WBHF

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Overview: What is Needed to Deploy STANAG 5066 over WBHF?

- Three "above modem" issues identified to enable WBHF deployment with applications
- Changes to S5066 to achieve good ARQ performance
  - Quick update
- Wideband ALE (WBALE)
  - Needed unless fixed frequency and channel size
  - (Primarily) for the modem and radio vendors/experts to specify
  - Expected to impact S5066 layer because of variable channel size (unlike narrowband ALE)
  - Potential benefits to involving application layer in WBALE
- Speed and Parameter Negotiation
  - Subject of this talk
  - Details in Isode white paper: "Optimizing STANAG 5066 Parameter Settings for HF & WBHF"
    - http://www.isode.com/whitepapers/stanag-5066-for-hf-and-wbhf.html

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STANAG 5066 ARQ Enhancements

- Window exhaustion significantly impacts operation over WBHF
  - And to some extent at faster narrowband speeds
- Two proposals
  - Harris: “Recommended STANAG 5066 enhancements for Wideband HF”
    - Presentation at BLOS Comms – Jan 2013
  - Isode: “Extending STANAG 5066 to improve ARQ Performance over Wideband HF Radio”
    - http://www.isode.com/whitepapers/extending-stanag-5066.html
- High Commonality
  - Extend Data PDU by one byte
  - Use backwards compatible encoding
    - New PDUs should be cleanly rejected by a compliant “old” implementation
    - Enables a “new” implementation to downgrade

ARQ Proposals: Differences and Convergence

- Key difference is use of the new byte:
  - Harris: 4 bits to extend Frame Sequence Number (FSN)
  - Isode: 8 bits to extend Frame Sequence Number (FSN)
- Koski/Kille consensus
  - Use 7 bits to extend Frame Sequence Number (FSN)
  - Use the last bit for:
    - Extend the FSN; or
    - Increase DPDU size from 1024 to 2048
  - Either option seems fine
  - Make measurements to decide on the best approach
- A single agreed approach seems highly likely

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Why Consider STANAG 5066 Parameter Setting?

- No options for WBHF waveforms: so have to do something
- Seems a useful opportunity to consider state of the art
  - Isode observations in trials suggests there is significant scope for improvement
- Modern Applications
  - STANAG 5066 research and products seem focussed on optimizing for bulk transfer and in particular email
  - We want to support a wide range of applications
  - In particular applications such as chat, where low latency is more important than maximising throughput

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Skywave and Groundwave

- Skywave
  - Focus of much HF Research
  - Rayleigh Fading and other variations
  - Significant intermediate term variation
  - CCIR model is best emulation
- Groundwave
  - Much less variation
  - Additive White Gaussian Noise (AWGN) is best emulation
  - Operationally very important, especially Maritime
- May be a significant factor in parameter approach

The choices to be made for S5066 Transmission

- Speed (Waveform)
- Interleaver
- DPDU Size (the unit of error and ARQ retransmission)
- Transmit Length (1-127.5 seconds)
- Need to decide (and fix) parameters at start of transmission
  - Based on information available at that time

“Classic” STANAG 5066 Data Rate Change

- Receiver control with Sender veto
- Several handshakes and then both ends restart together
  - Enables restart with both ends on same settings
  - Essential for older waveforms
- Autobaud Waveforms change this
  - No need for the handshaking
  - Any new variable speed HF deployment is going to use STANAG 4539 or MIL STD 188-110
  - STANAG 5066 does allow for this
    - But does not go far enough
    - Some interpret as retaining receiver control

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New Approach: Big Picture

- Sender control
- Receiver provides information to sender to help sender make best choices
  - The receiver has access to information not directly available to sender (e.g., SNR)
- Sender also has key information
  - Data to be sent
  - QoS requirements
  - Conditions and historical behaviour
- So sender is the right place to decide
- Can all be achieved with the standard S5066 EOW (Engineering Order Wire) single byte message mechanism
  - Just need to define new messages

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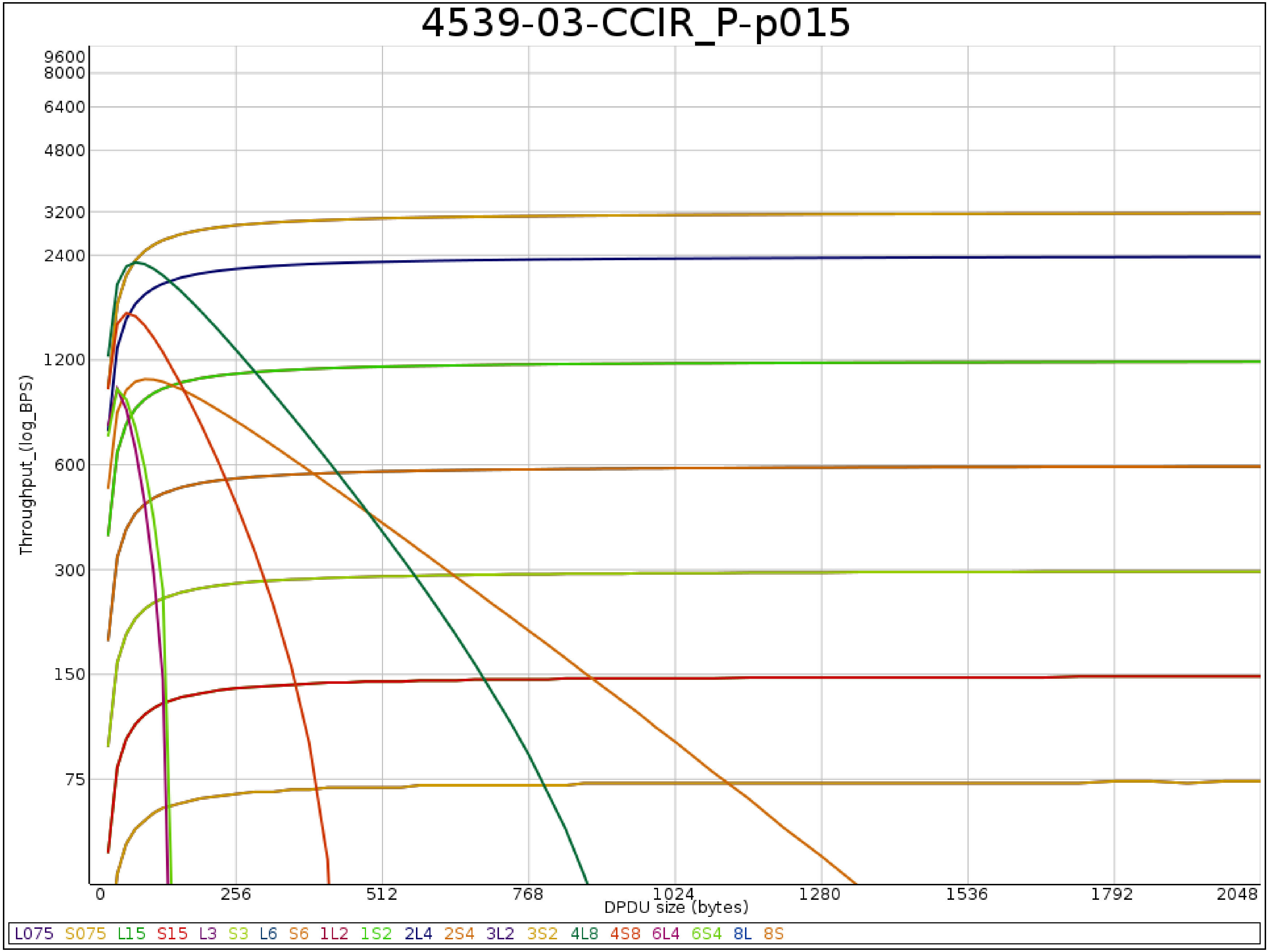
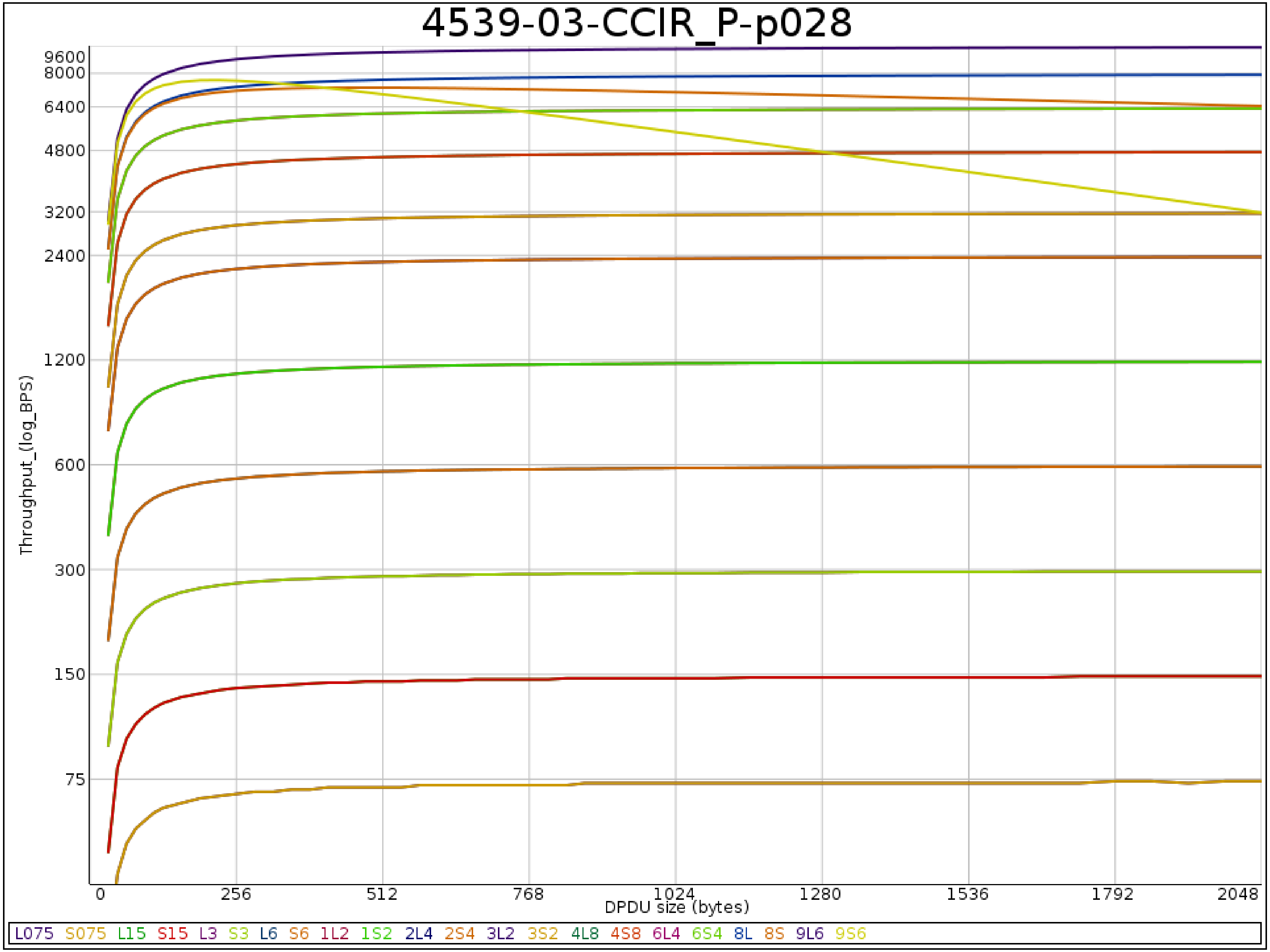
Testing Approach

- 3 Rockwell Collins HSM 2050 HF/WBHF Modems
  - Provide modem pair and connecting channel simulator
  - Thanks: Randy Nelson, Mark Jorgenson, & Rockwell Collins
- Send traffic using Isode “HF Tool” and modem drivers
  - Known data patterns, so can measure “bit characteristics”
  - Vary SNR at 1 dB intervals
  - Send using different waveforms and interleavers
- Analyse results to determine effect of varying DPDU size
  - Model STANAG 5066 use of the modem layer
  - MUCH faster than running tests with STANAG 5066 (and as accurate)

Example 1: CCIR Poor +15dB (flat)



2: CCIR Poor + 28db (Short Interleaver Drop-off)



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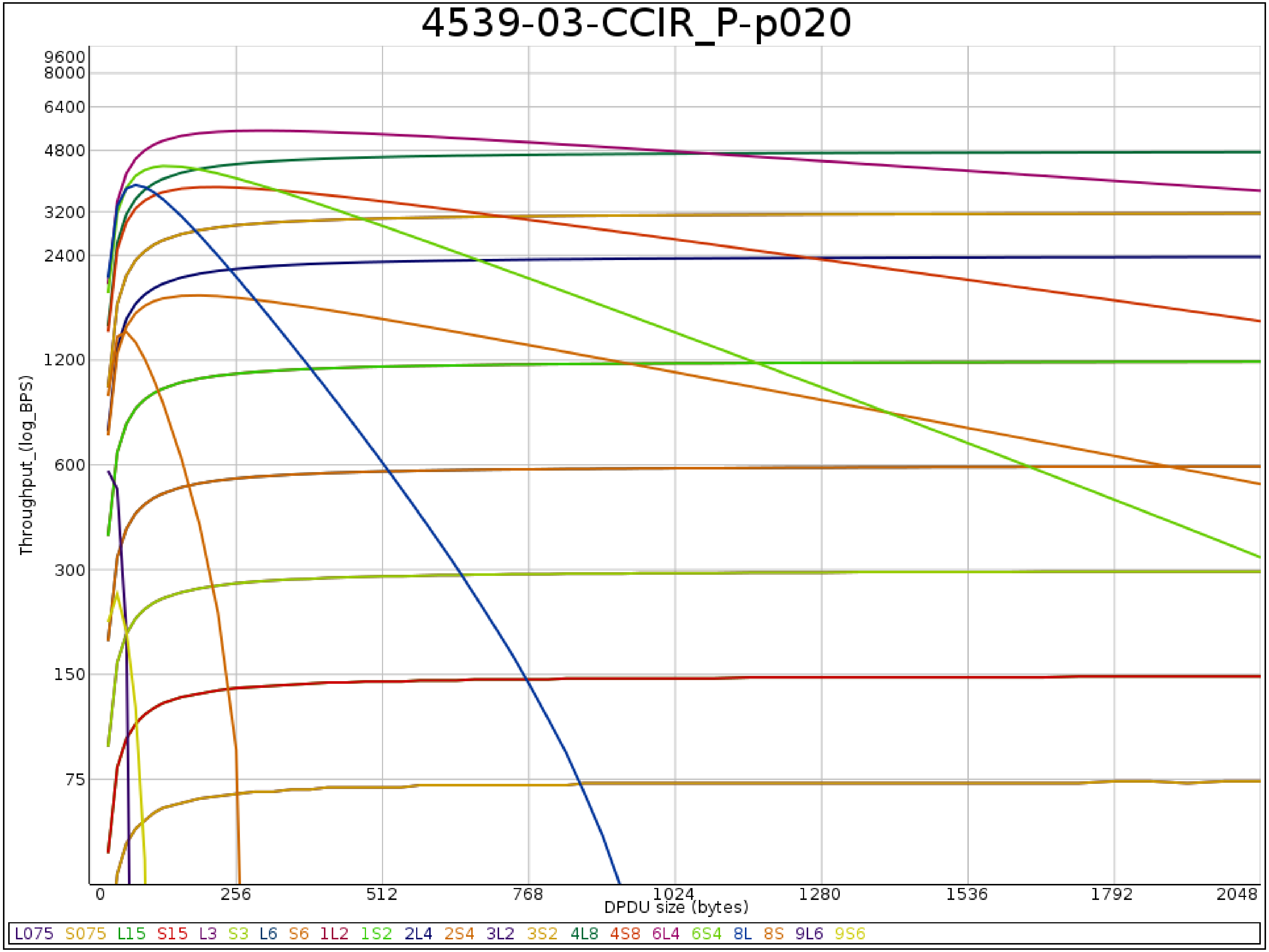
Example 3: CCIR Poor +20dB (broad peak)



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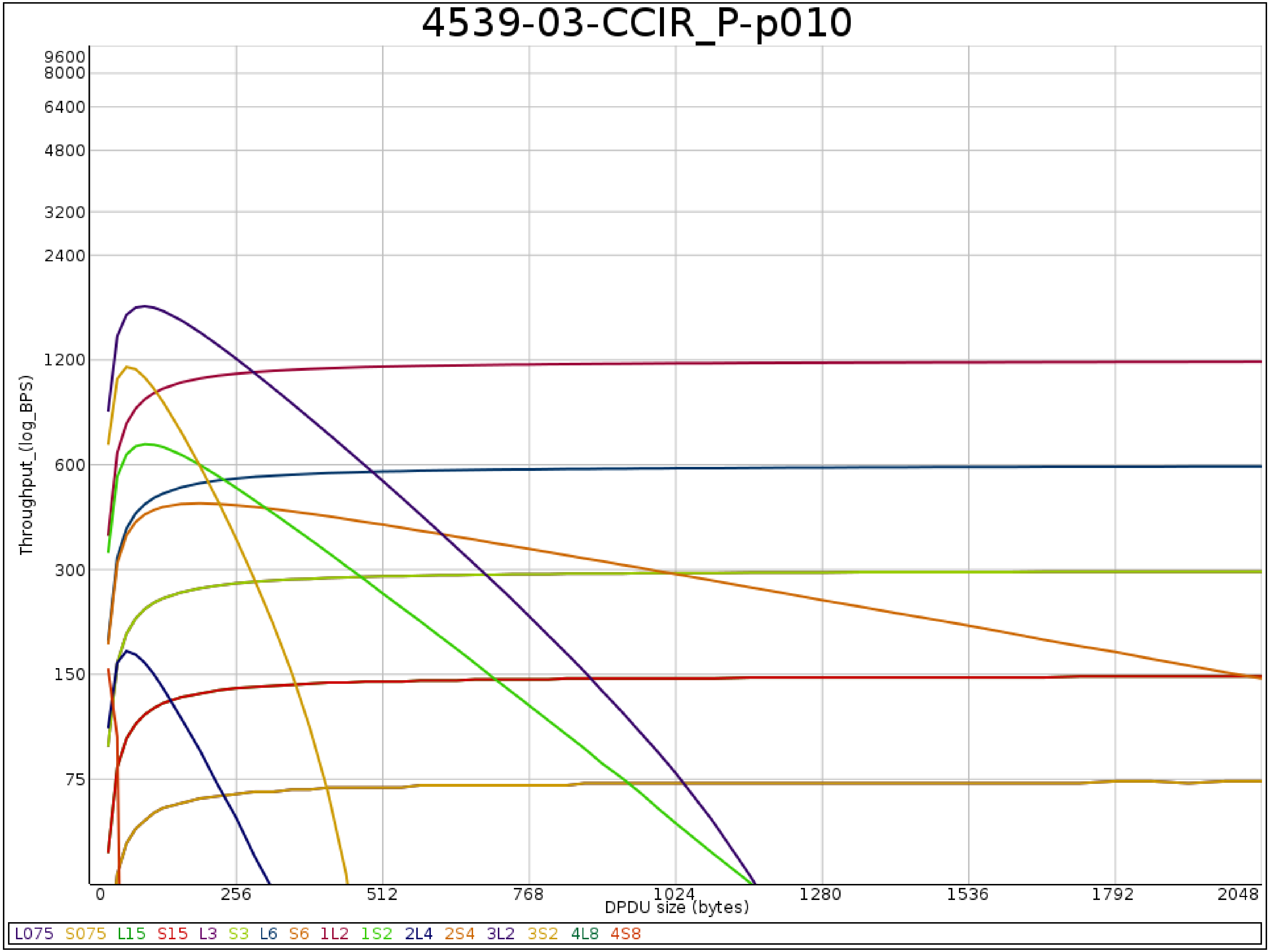
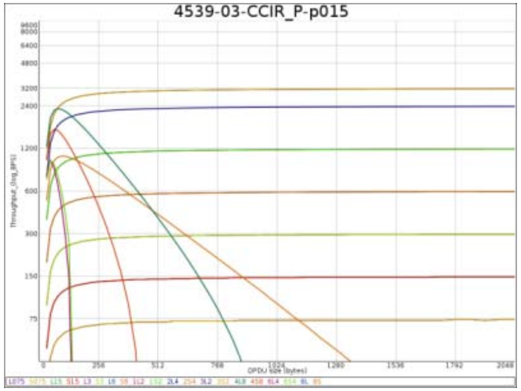
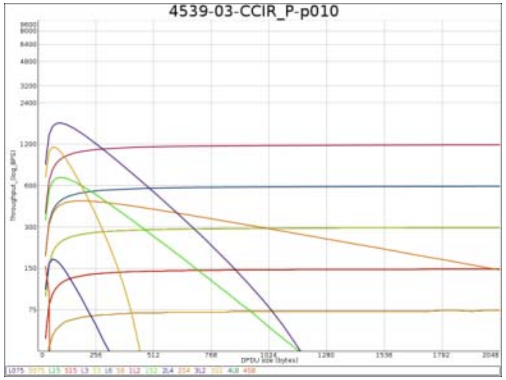
Example 4: CCIR Poor +10db (sharp peak)



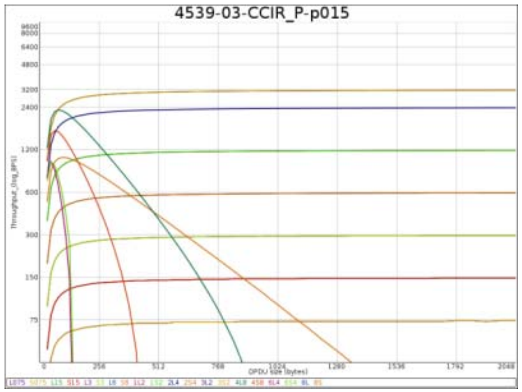
What is happening as SNR changes

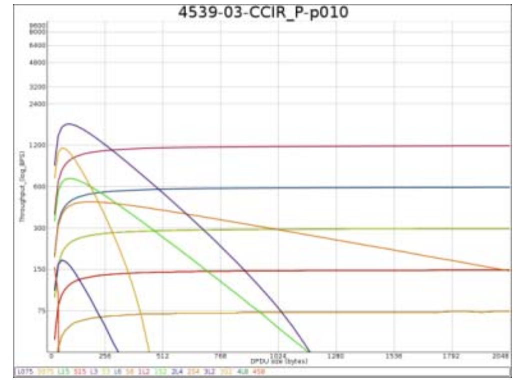




- There is a repeated cycle of graph shape as SNR changes
  - Start with “flat line” (and consider conditions getting poorer)
  - Gradually falls off to form sharper and sharper peak
  - Peak falls further and graph reverts to flat line at next speed down
- Primary graph forms are “flat” and “peak”
  - About evenly split
  - Peaks are mostly “broad”

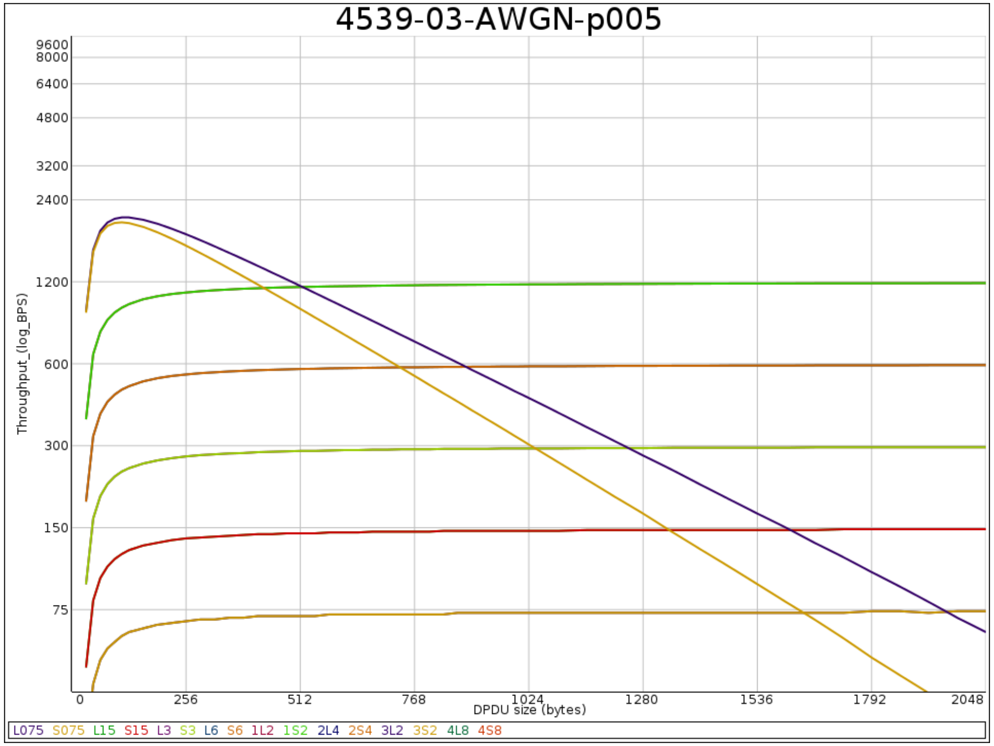
Implications for Data Rate Change





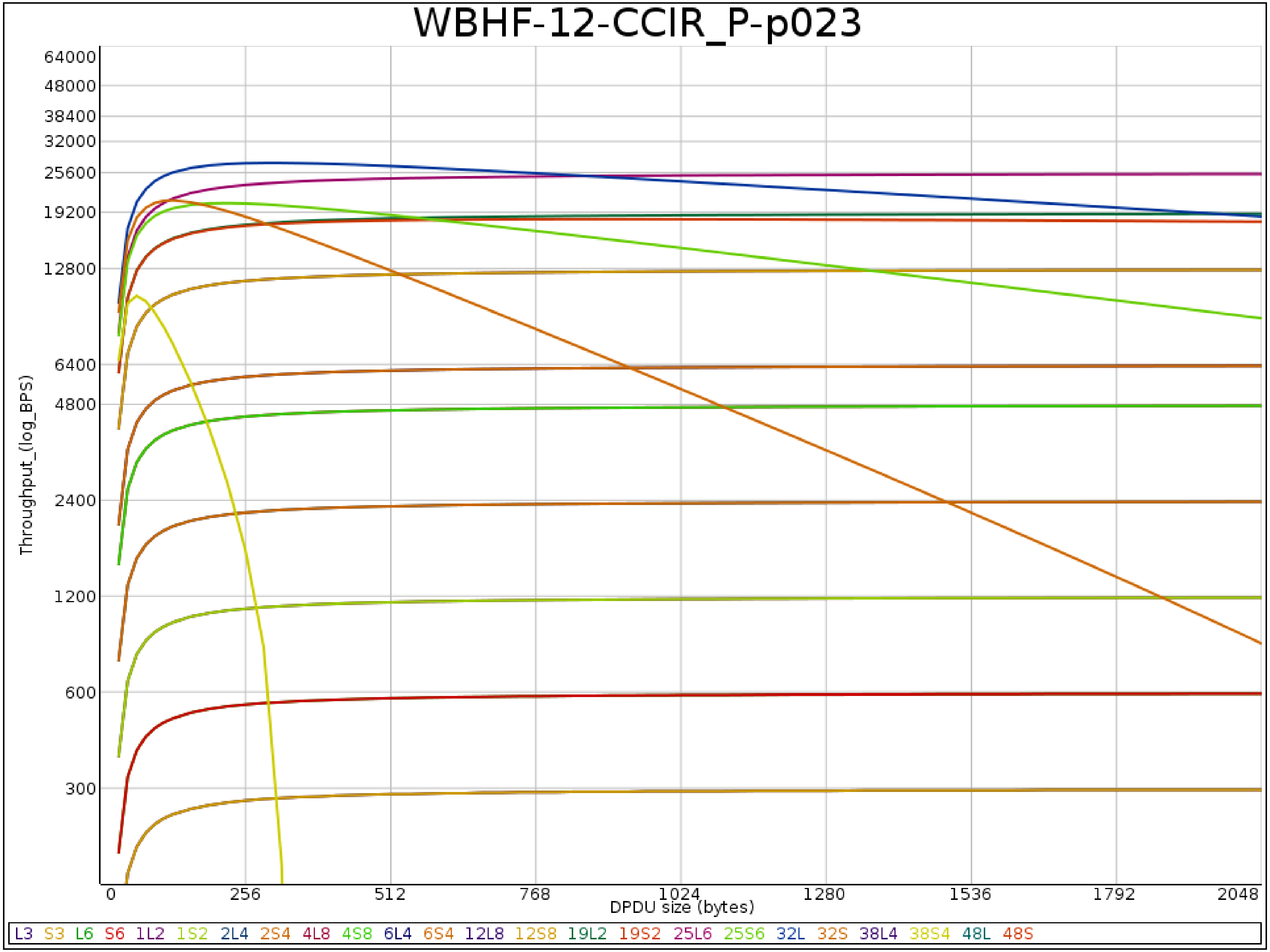
- The graph shapes explain Trinder/Brown oscillations
  - Oscillation means significantly sub-optimal performance
  - Oscillation will occur on “flat” graphs
  - A consequence of a simple FER (Frame Error Rate) approach
- Interesting implications on optimum DPDU size
  - For flat graph use Max DPDU size (FER close to zero)
  - For “peak” graph need to tune DPDU size
    - Can measure FER and work out optimum DPDU size
  - Simple fixed DPDU size strategy is clearly sub-optimal
  - In slowly varying conditions, may well make sense to keep speed fixed and vary DPDU size to tune performance

AWGN (and Groundwave)

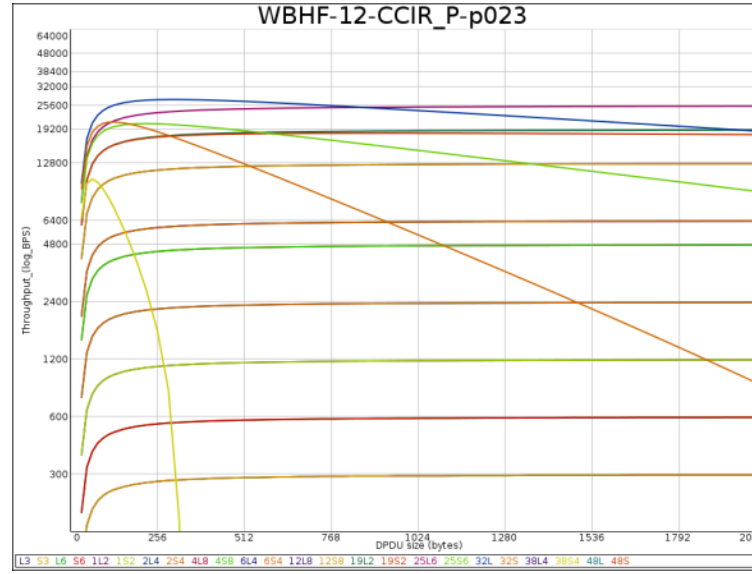


- Picture broadly similar to CCIR Poor
- Similar split between Peak and Flat
- Effect of longer interleaver less marked
- The rate change model applies to Groundwave

WBHF: Example: CCIR Poor +23db 12 kHz

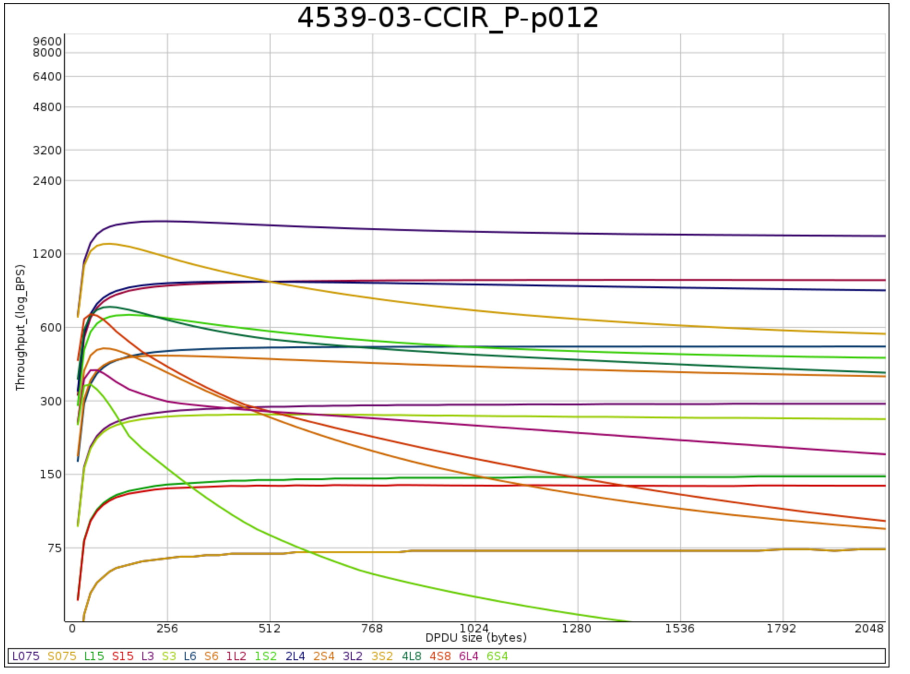


WBHF



- Shapes of graph similar to Narrow Band HF
  - Approximately even split of “flat” and “peak”
- Nothing to indicate the WBHF needs to be handled differently
- DPDU size notes
  - Often shorter DPDU size (200-300 bytes) is optimal
  - Suggests “8th bit” might be best allocated to FSN

Intermediate Term Variation



- Intermediate Term Variation (ITV)
  - Variation of order 10 seconds to 2 minutes
  - Timescale of high relevance to STANAG 5066 transmissions
  - Typical 4 dB Variation for Skywave
- We tried to simulate ITV (see graph above)
  - We are not convinced that the analysis is valid
  - However, we believe effects will be significant
  - This sort of behaviour would explain Trinder/Gillespie
- OTA Measurements are needed
  - In a manner to enable S5066 performance analysis

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Interleaver Choice

- Long Interleavers give better performance
  - Well known in the literature and applies to WBHF:
    - “Investigating the Effects of Interleaver Size and FEC Code Constraint Over the-Air for the US MIL-STD-188-110C Appendix D WBHF Waveforms” (John Nieto, Harris, HFIA York 2012)
- Modern Interleavers use tail-biting and so do not have an overhead
  - Provided that you fill the blocks
- For bulk data, use of long interleaver is a no-brainer
  - Use the longest interleaver available
  - Choose a transmit length to fill an exact number of blocks
- For shorter (fixed length) transmissions, there is a more complex decision
  - Need to consider efficiency of block usage before choosing a very long interleaver

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Optimizing for High Throughput and Low Latency

- Applications transferring bulk data (e.g., email) remain important
  - Choose speed and DPDU size to optimize for throughput:
    - May have high FER
  - Long transmissions (all or most of 127.5 seconds)
  - Longest possible interleaver
    - Tune exact transmission length to fill an exact number of blocks
- Some applications need optimizing for latency
  - Applications with small PDUs such as XMPP (text chat)
  - Acknowledgments (which may be from bulk transfer in the opposite direction)
  - Choose a slow speed where zero error rate is expected
    - Usually straightforward as actual transmit time will be low

More Complex Application Scenarios

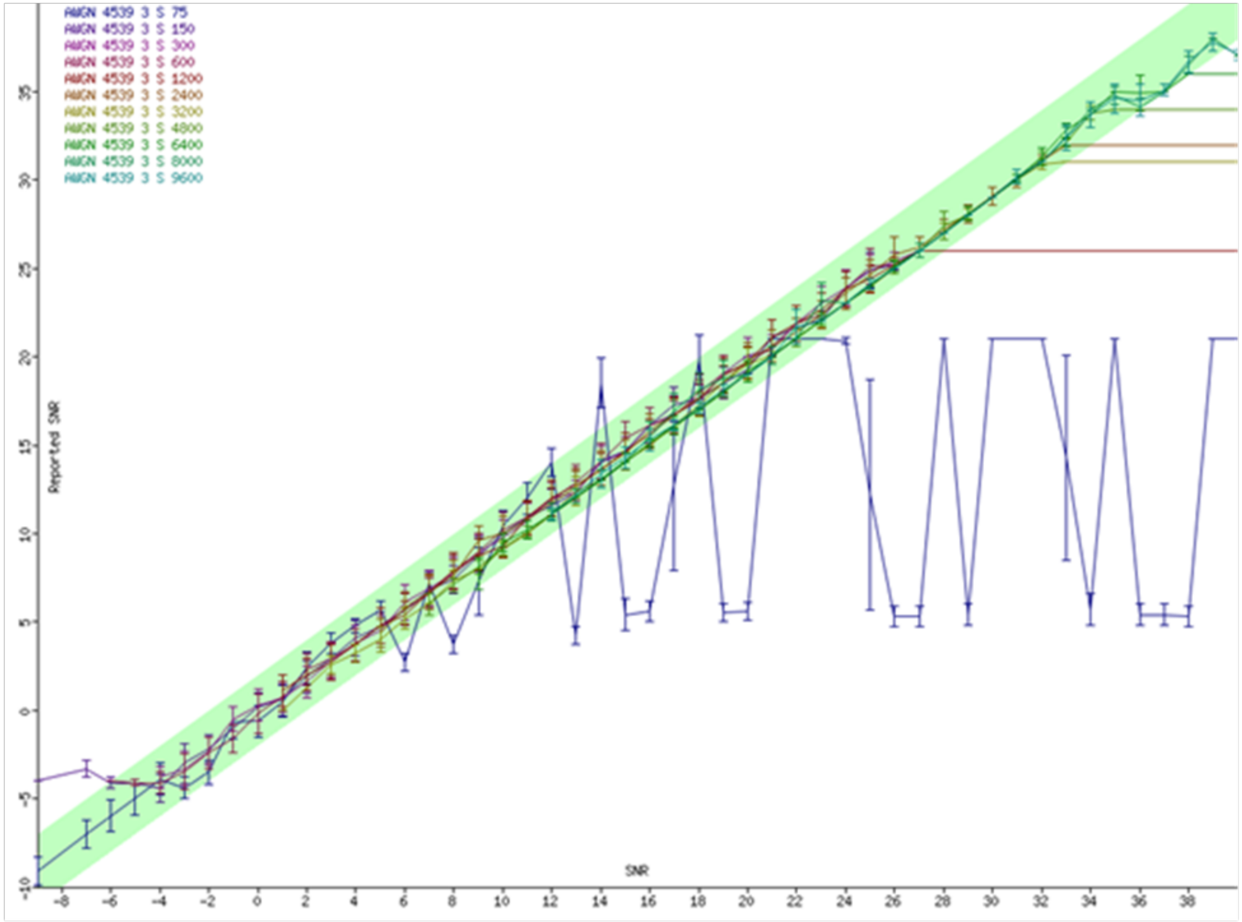
- Medium sized transfers, where low latency is important
  - If the time to transfer is significant, may be a complex trade-off between speed and error rate
    - Slower speed reduces probability of needing retransmission but increases latency
- Last bytes of a large transfer
  - If bulk transfer is being handled at speed with high FER, may make sense to slow down as last bytes (likely retransmissions) are sent
- Mixed traffic
  - Consider mix of chat and email
  - If you give chat complete priority may block email altogether
  - If you give email priority will slow chat dramatically
  - Intermediate approach may make sense
  - QoS extensions to S5066 SIS protocol seem desirable

Using SNR to Select Speed

- It has been argued that SNR can be used to select transmit speed
- Ideal is that receiver will measure SNR during ARQ soft link establishment
  - Typically a couple of seconds
  - Measurements suggest this is sufficient time to get a stable SNR reading
- Key question: how accurately can SNR determine best speed
- Tests done to measure SNR against simulated SNR
  - Rockwell Collins HSM 2050

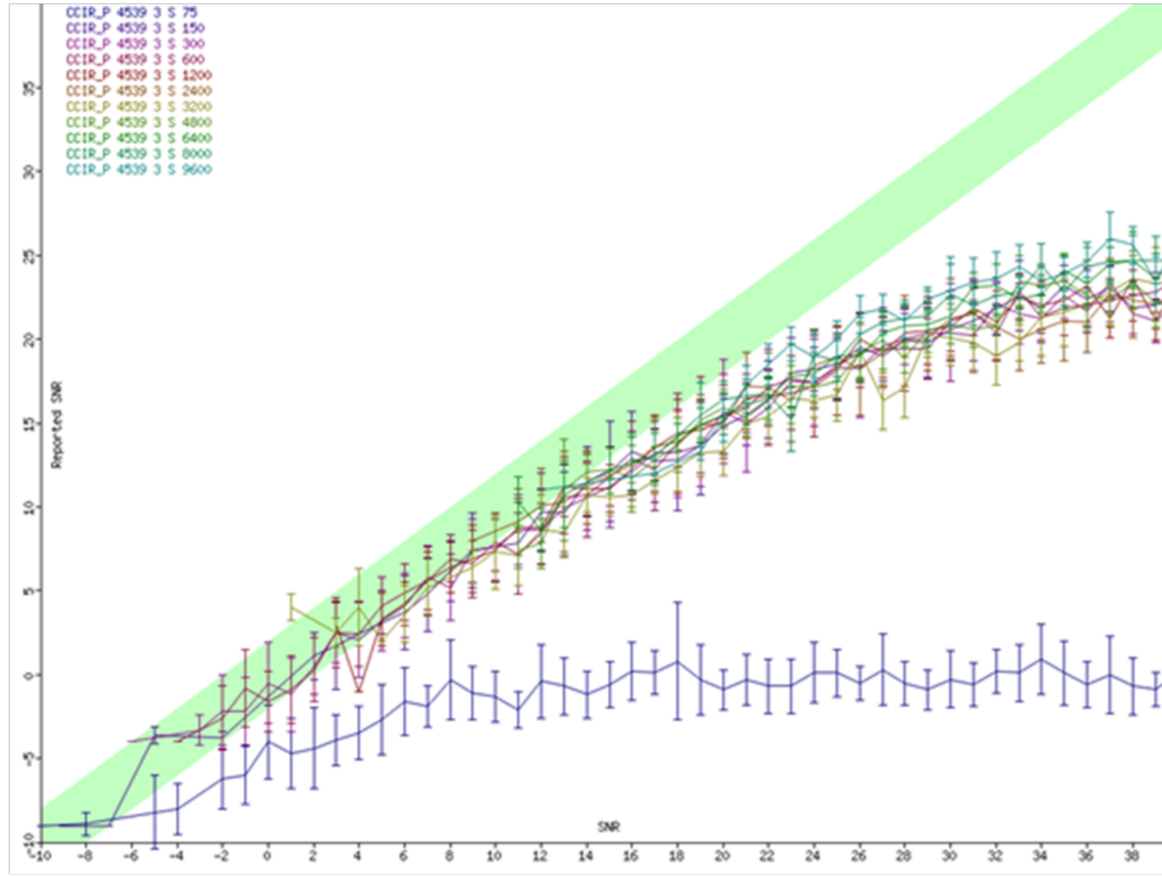
SNR: AWGN

- Measurements for AWGN look good
- For Groundwave should be able to get to best “flat speed”
- Then use FER to fine tune



SNR: CCIR Poor

- SNR Measurement variation for CCIR Poor higher
- Appears too high a variance to be able to get “best speed” for Skywave
- Should enable quick access to reasonable speed
  - Avoid stepping up through very slow speeds
- Use FER to get to best point



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Proposal for a Receiver to Sender Protocol

- Use STANAG 5066 EOW (Engineering Order Wire) one byte messages to enable receiver to share information with sender
- Communicate settings for speed optimized for throughput
  - One EOW message for best speed
  - One EOW message for best DPDU size
  - DPDU size likely to be modified more frequently for fine tuning
- Communicate information on error rate of different speeds
  - The “optimized for throughput speed and up to seven slower speeds
  - Estimated FER for each speed
  - One EOW format can communicate information on two speeds
  - Will share info down to a speed with expected zero error rate
  - This will facilitate a sender choosing between low latency and high throughput

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Proposal for a Receiver to Sender Protocol (2 of 2)

- Use a “Probe” approach to investigate faster speeds
  - One above the recommended (optimized throughput) speed
- EOW “Throughput Probe” messages enable sender to indicate:
  - Probe likely or unlikely to succeed (or neutral view)
  - Recommended DPDU size
  - Don’t send probe (advice to prevent oscillation)
- Sender options
  - Don’t send probe (e.g., if bulk transfer just finishing)
  - Send a short transfer as a probe
- Receiver action after probe
  - Modify recommendations on optimum throughput if probe shows better setting
  - Send “don’t probe” if probe does not show a better setting
  - Monitor SNR and suggest probe again if conditions improve

Conclusions and What Next

- We have a good framework for:
  - Extending STANAG 5066 to work over WBHF
  - General improvements to STANAG 5066 relative to current state of the art
- Aim to demonstrate this approach in 2014
  - Isode's Icon 5066 (modem-independent STANAG 5066 server) will support the protocol and approaches described here
- Need OTA Measurements on ITV (Skywave)
  - Isode has tools to enable suitable measurement
  - We expect to use these in OTA tests in 2014
  - We are interested in further OTA tests

Any Questions?