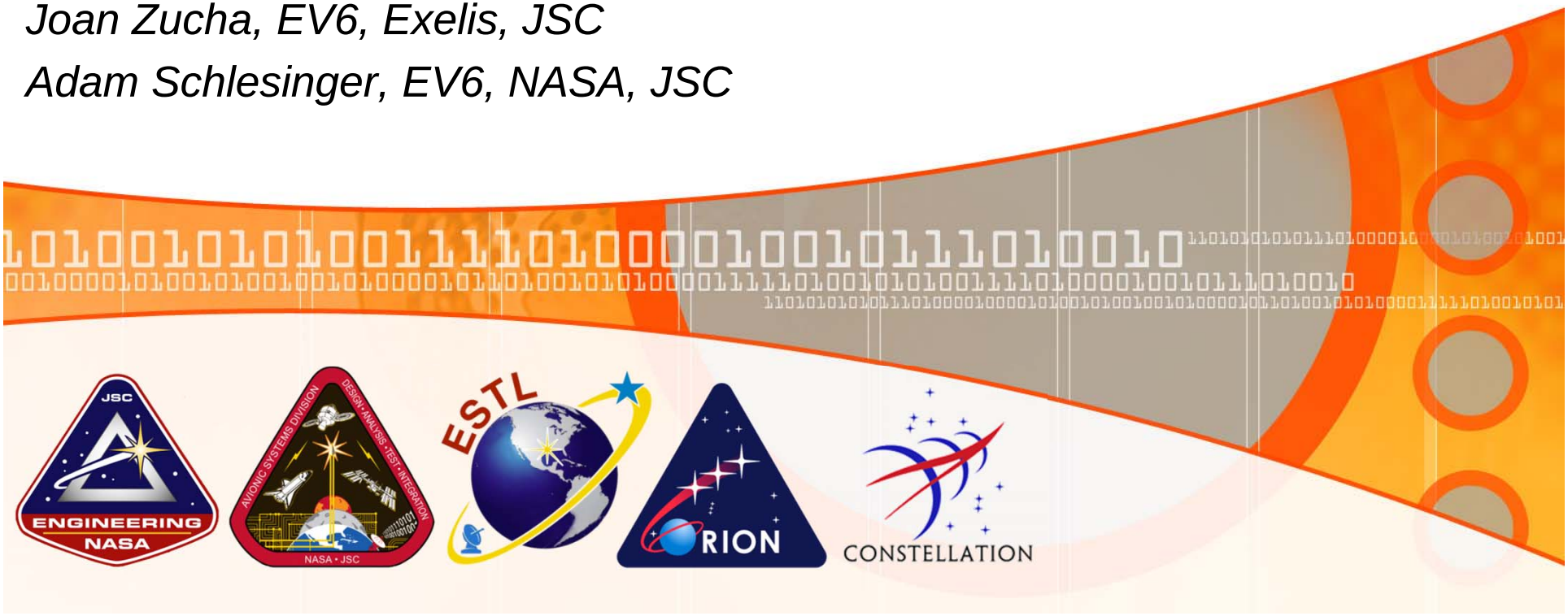
Soft Decision Analyzer

Chatwin Lansdowne, EV8, NASA, JSC

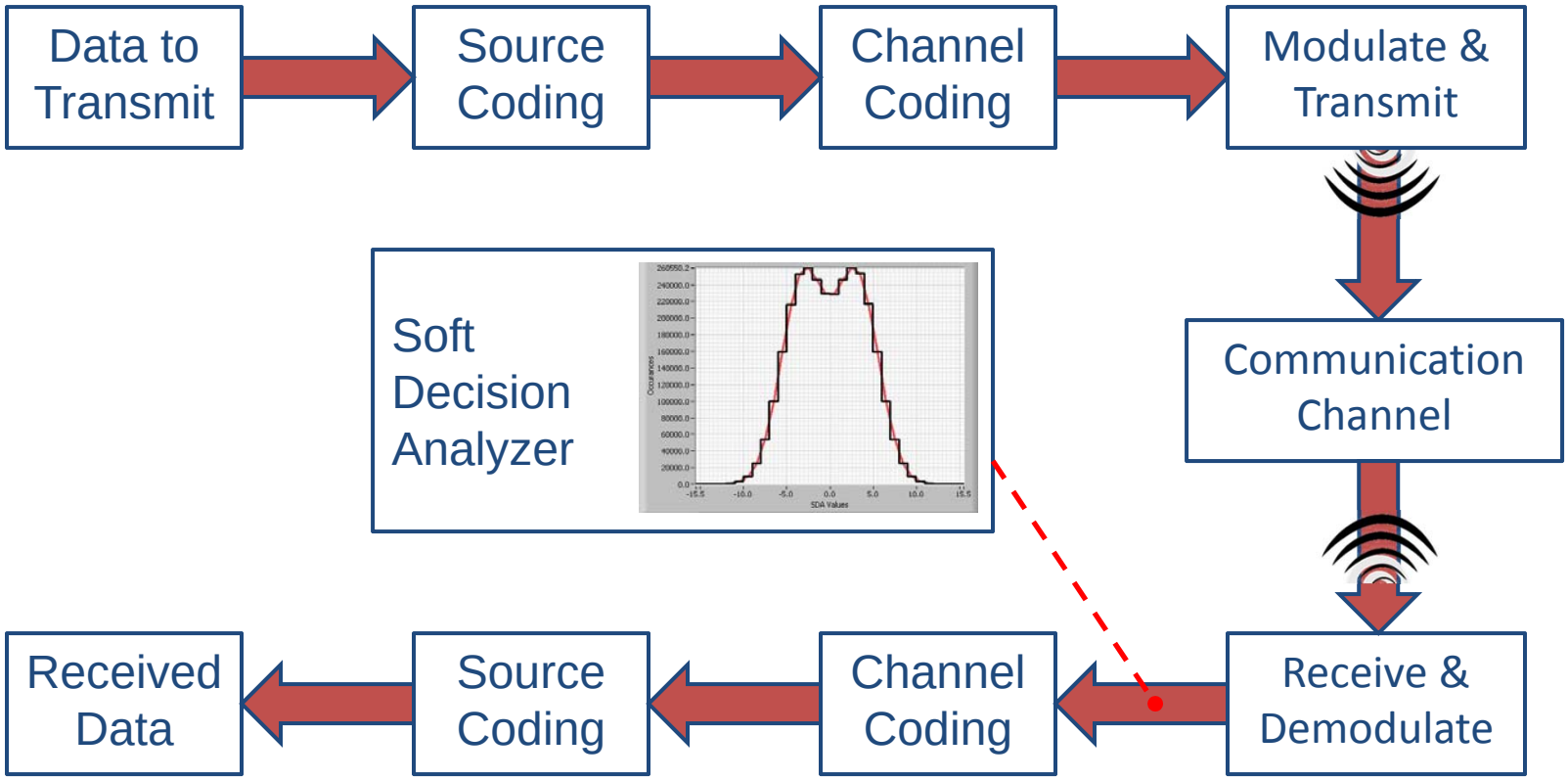
Glen Steele, EV3, NASA, JSC

Joan Zucha, EV6, Exelis, JSC

Adam Schlesinger, EV6, NASA, JSC



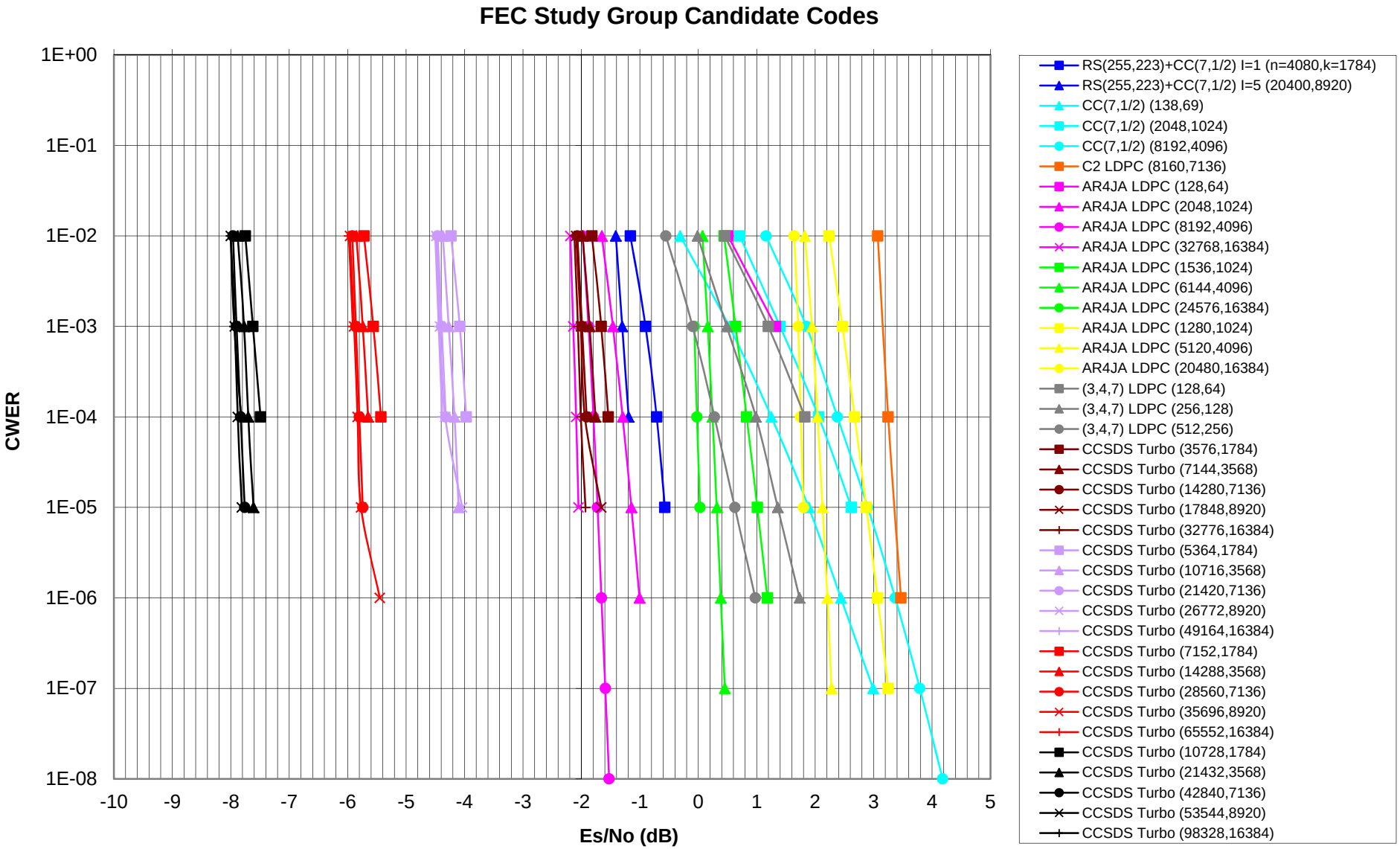
Communication System
with Open-Loop Testing



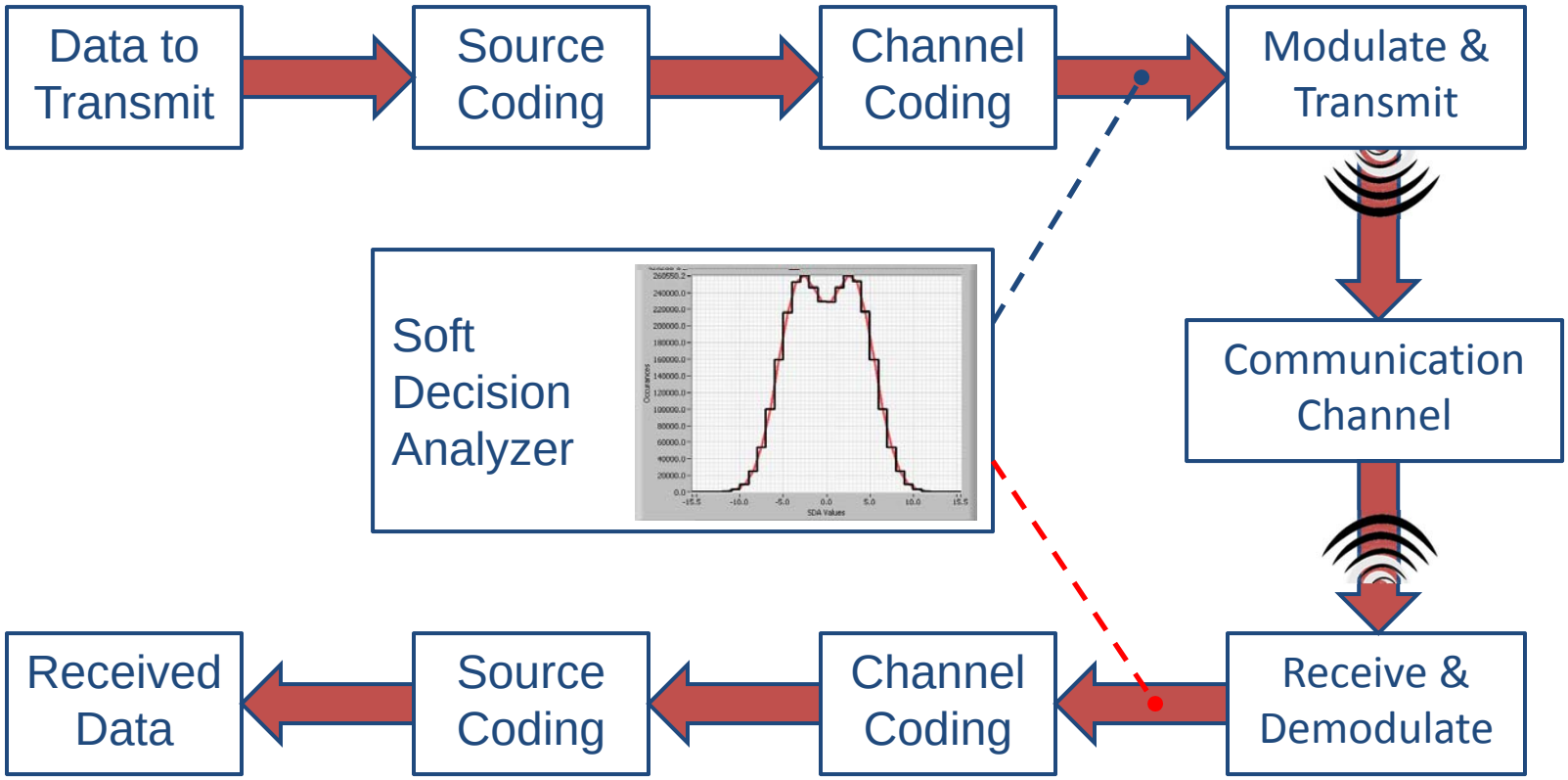
High-Performance Soft Decision Block Codes

- Modern block decoders can operate at 10% SER or higher
- The decoder cannot operate on a PRBS BERT pattern
- If you break the link to change the data pattern, it reacquires with a different alignment, and you change the performance
- For testing soft-decision block codes with practical receivers and a practical channel, an instrument was needed that could
  - **Analyze framed code-blocks (“live data” not just PRBS)**
  - **Detect and track receiver threshold effects like slips and rotations**

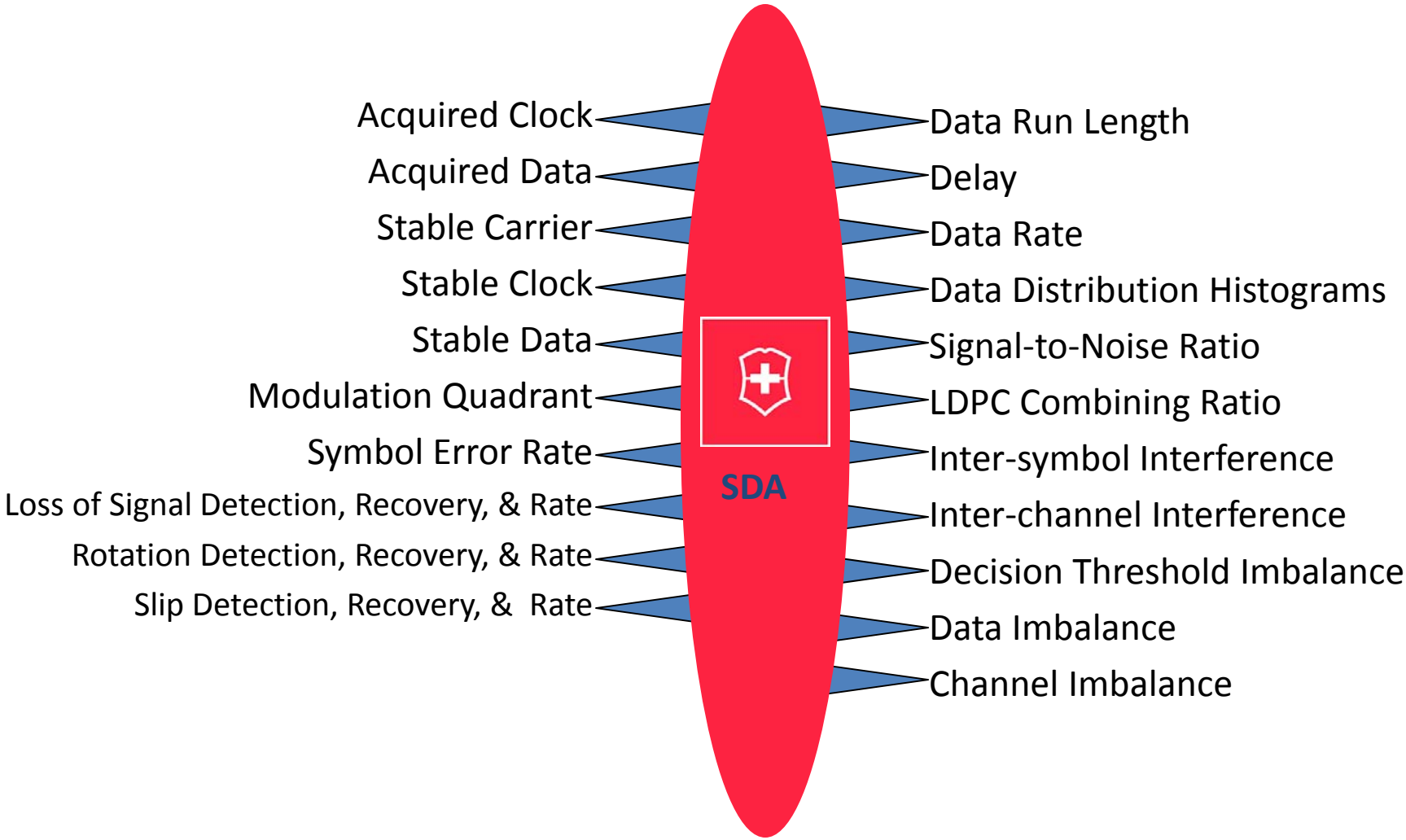
As Modern Error Correction Approaches the Shannon Limit, Receivers Must Contend with Ultra-Low SNRs



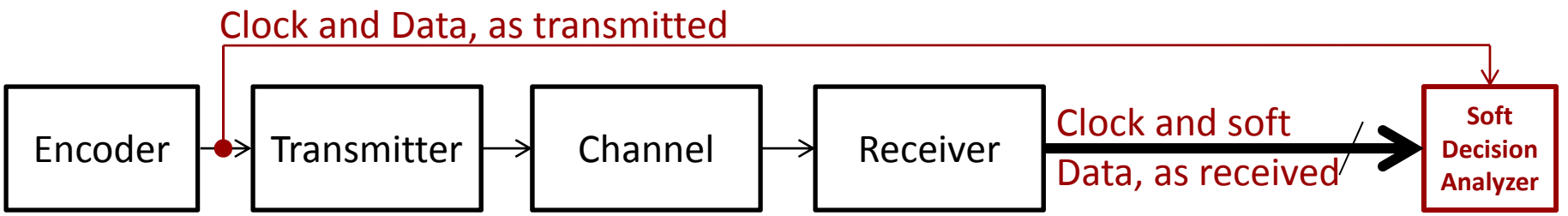
Communication System
with Closed-Loop Testing



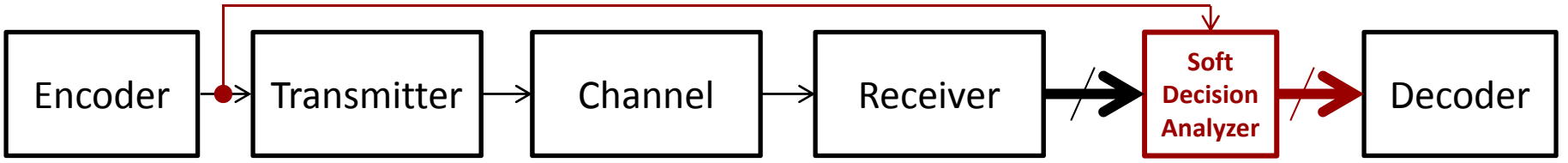
SDA Measurable Parameters



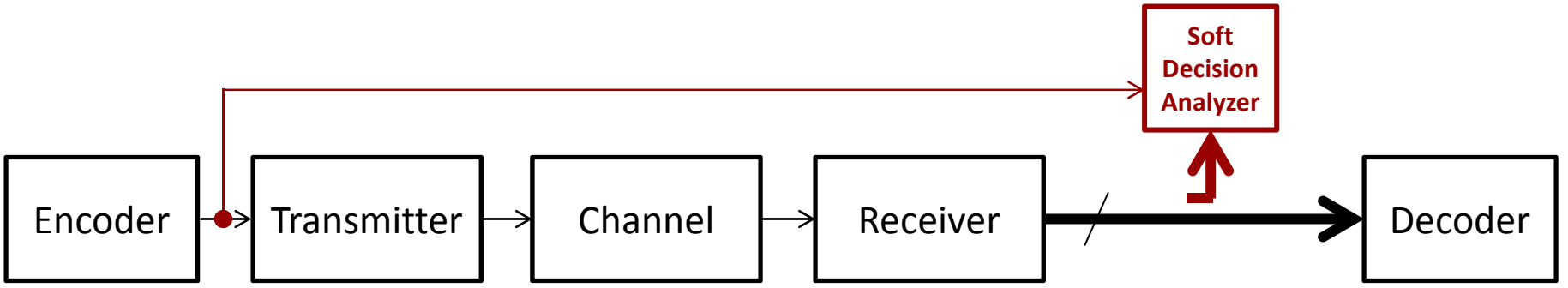
Connecting Test Points



1) Receiver Test with Transmitter and Channel, no Decoder



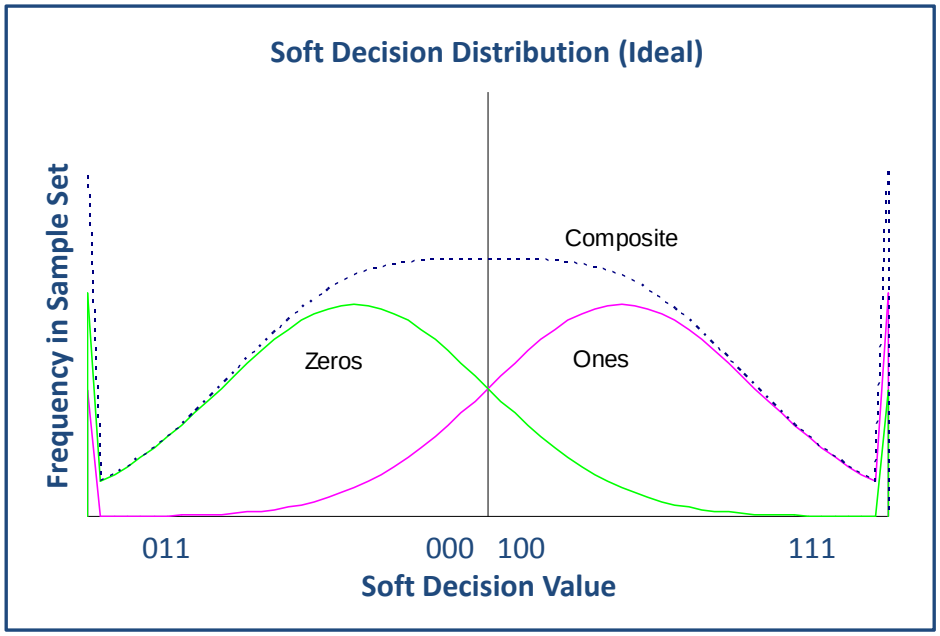
2) Receiver Test with Transmitter and Channel, Translation for Decoder



3) Receiver Test with Transmitter and Channel, Integrated with Decoder

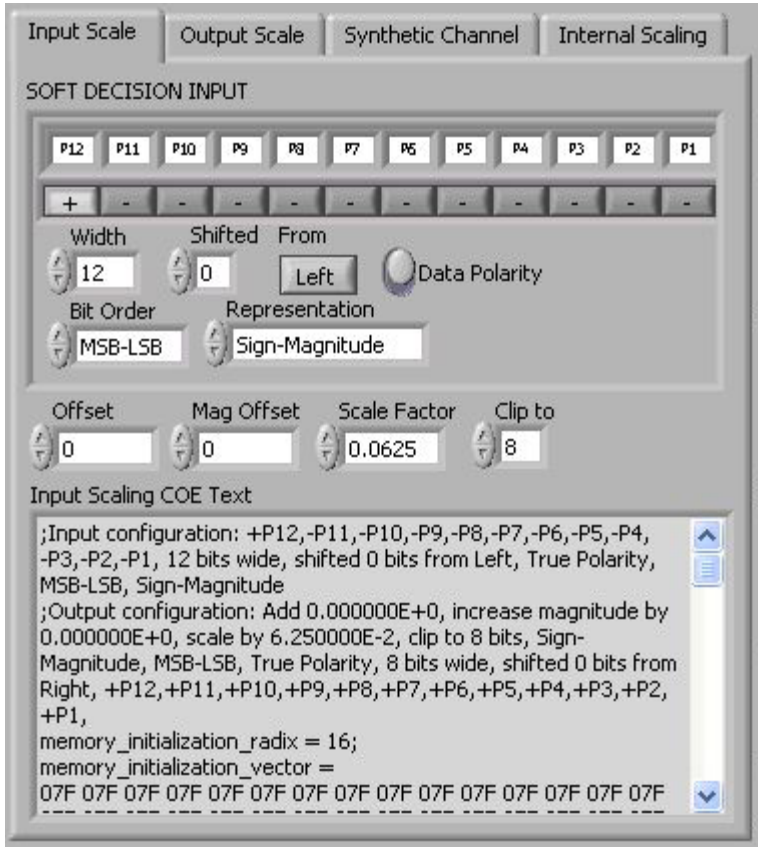
Hard vs. Soft Decision

- For binary communications, hard decisions are simply the 1's and 0's. Soft decisions also contain the 1's and 0's, but also a level of confidence.
- The number of confidence levels is determined by the number of bits used for soft decisions.
- Example of 3-bit soft decision:
  - 011 (Strongest 0)
  - 010
  - 001
  - 000 (Weakest 0)
  - 100 (Weakest 1)
  - 101
  - 110
  - 111 (Strongest 1)

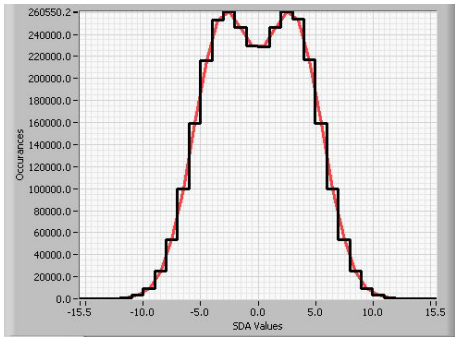


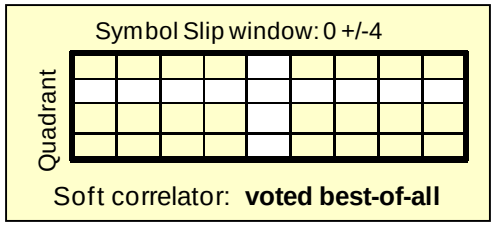
Input and Output Scaling

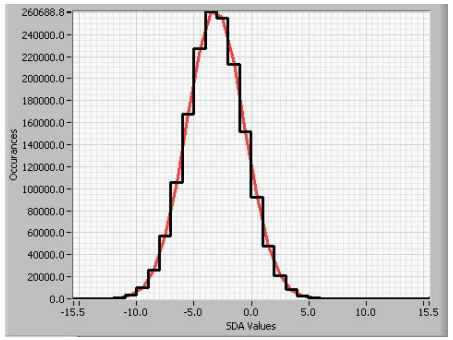
- Input and output scale tables are used to accommodate variation in bus widths, number representation, and statistical average.
- Problems with logic polarity and pin swapping can be corrected at the click of a mouse.
- The output bus allows SDA to translate between a transmitter and a receiver built to different specifications.

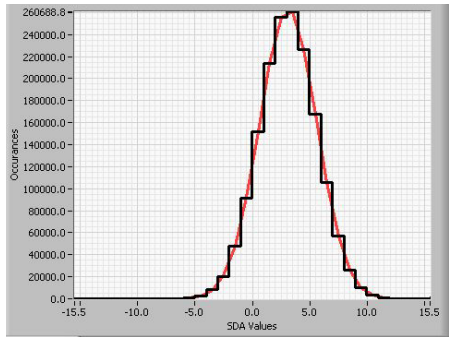


Correlators





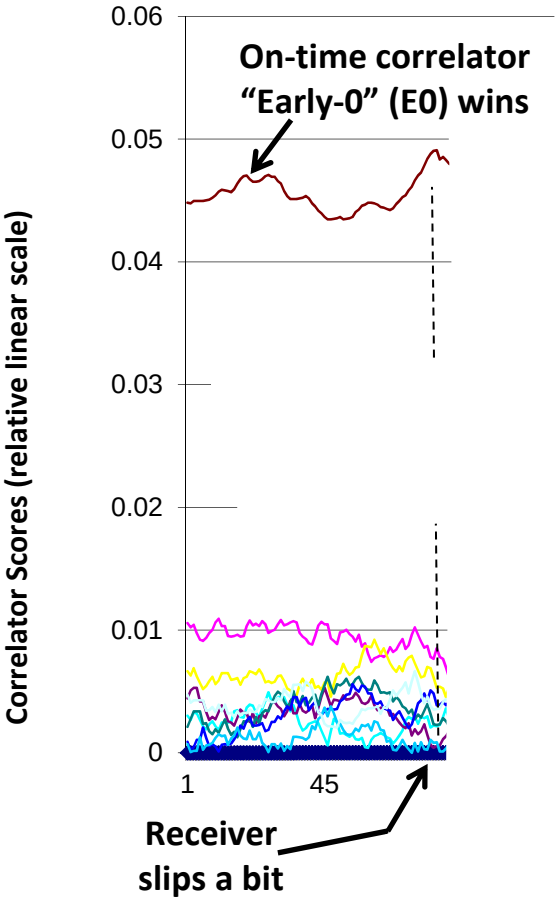




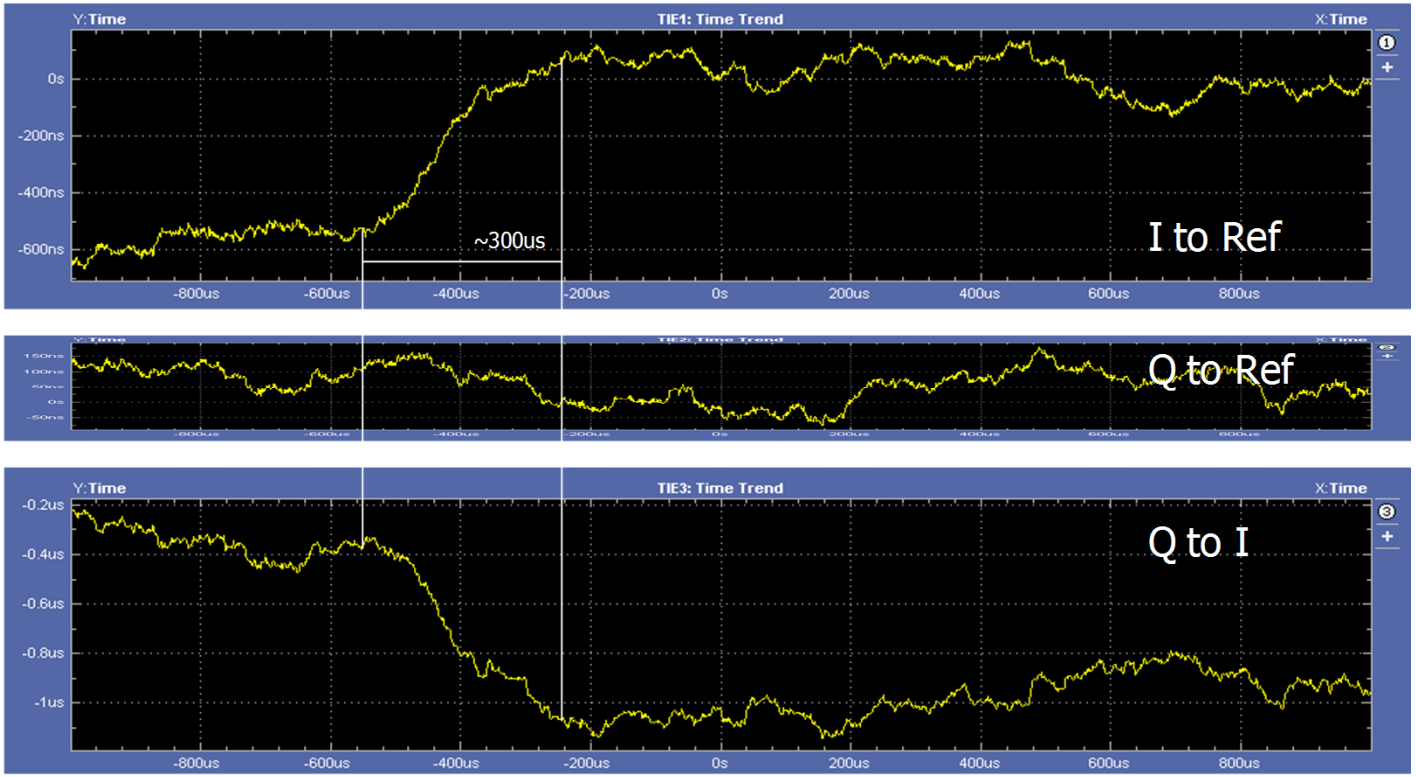
Uncorrelated Data **SDA Correlated Data**

- SDA can acquire and maintain reliable correlation between Reference and Test data streams at SERs in excess of 30%. At 17% SER, the SDA can recover from a slip in less than 600 bits.
- Alignment is continuously monitored. Each symbol interval, correlation is evaluated in each of four quadrants for each of nine alignments. The window is re-centered after each slip detection.
- A variable-width correlator (16 to 512 bits) is available, trading resolution for stability
- Three parameters control hysteresis and squelch
  - Variable-length running totals of how many times each alignment has been best, used to select a winner
  - A variable-length lock-out following an alignment change
  - A correlation quality threshold invokes flywheeling

Maintaining Alignment

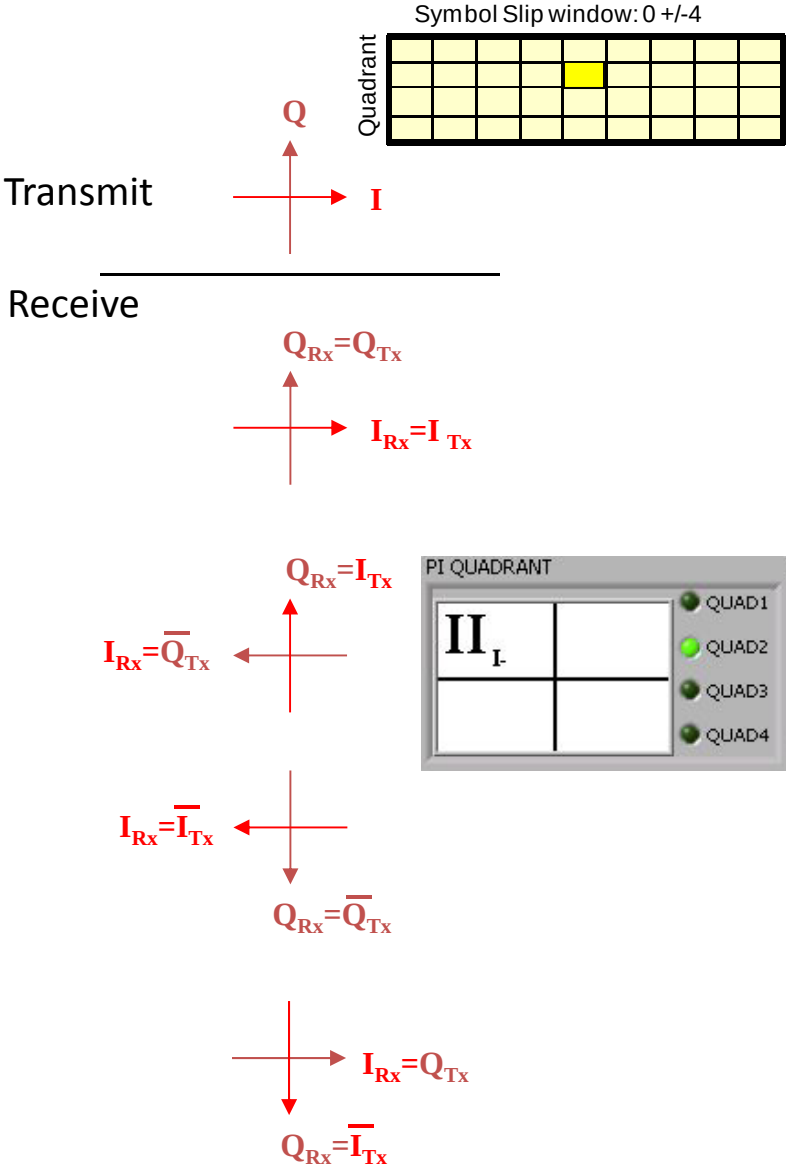


Slips, in a Real Symbol Synchronizer

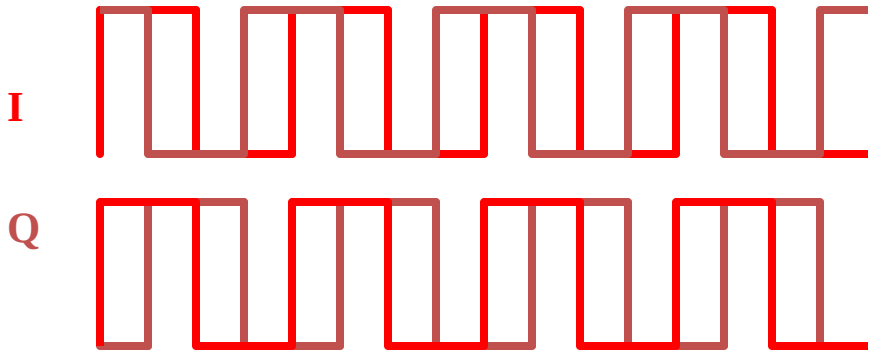


- Phase jitter trend measured during a slip on the I channel
- Transition time of the slip depends on the loop bandwidth, here it took 300 bits

Constellation Rotations



- QPSK rotation by one quadrant (a 90° slip of the carrier tracking loop) causes channel swapping.
- Channel swapping means symbol synchronizer swapping.
- Due to symbol staggering, the symbol synchronizers are now integrating mid-bit to mid-bit.
- A half-bit slip one direction or the other must ensue to compensate.



Es/No Estimations

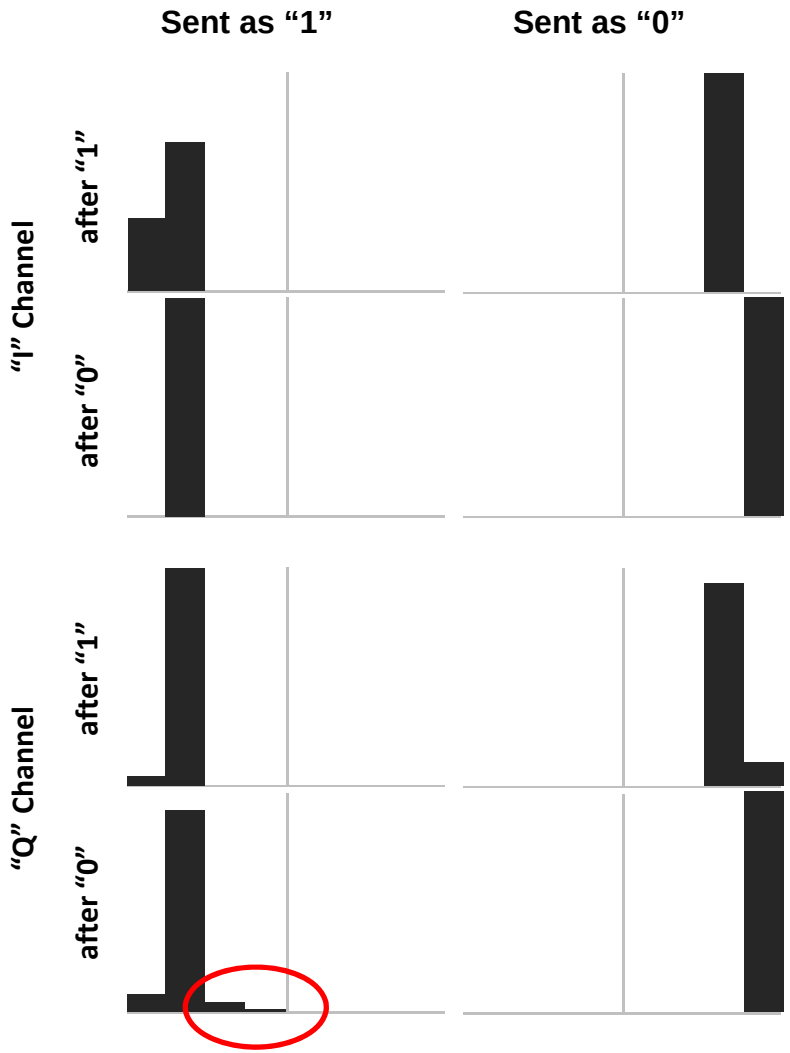
- Es/No from hard decision SER and inverse Q() (practical meaning and highly stable)
- Es/No from fitted bell curve (high stability but assumes Gaussian noise)
- Es/No from mean and standard deviation of **correlated** soft decisions (direct compare for many SNR estimators)
- Es/No from median and long-tail standard deviation of **correlated** soft decisions (less influenced by clipping, and no distribution assumed)

Quantified Imbalances

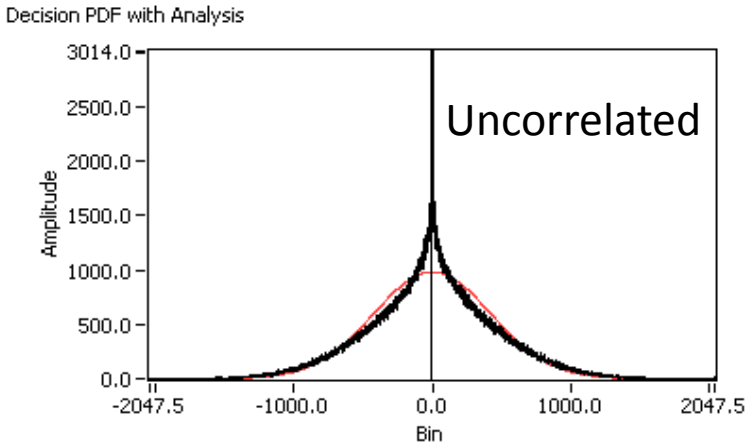
- Not just one, but 8 histograms are run concurrently and then analyzed for:
  - Data Imbalance
  - Logic Threshold Imbalance
  - Channel Imbalance
  - Transition Density
  - choice of Inter-Symbol Interference (ISI) or Inter-Channel Interference

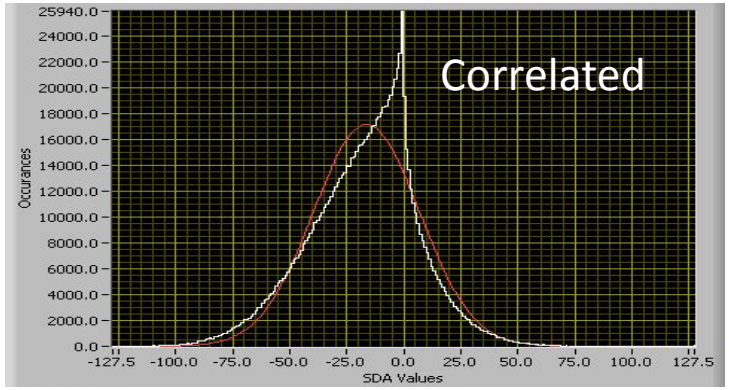
Actual Receiver Performance

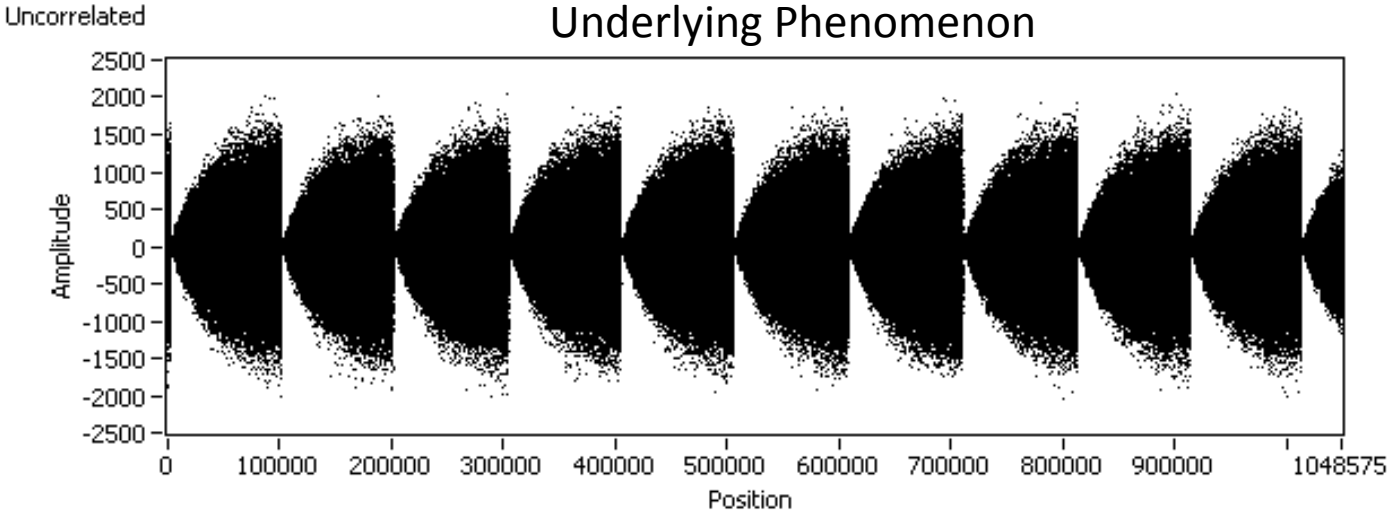
- Probability of Error is much higher for bits sent as a “1” following a “0”– but only for one of the two channels.



Correlated Histograms and Anomalous Behavior



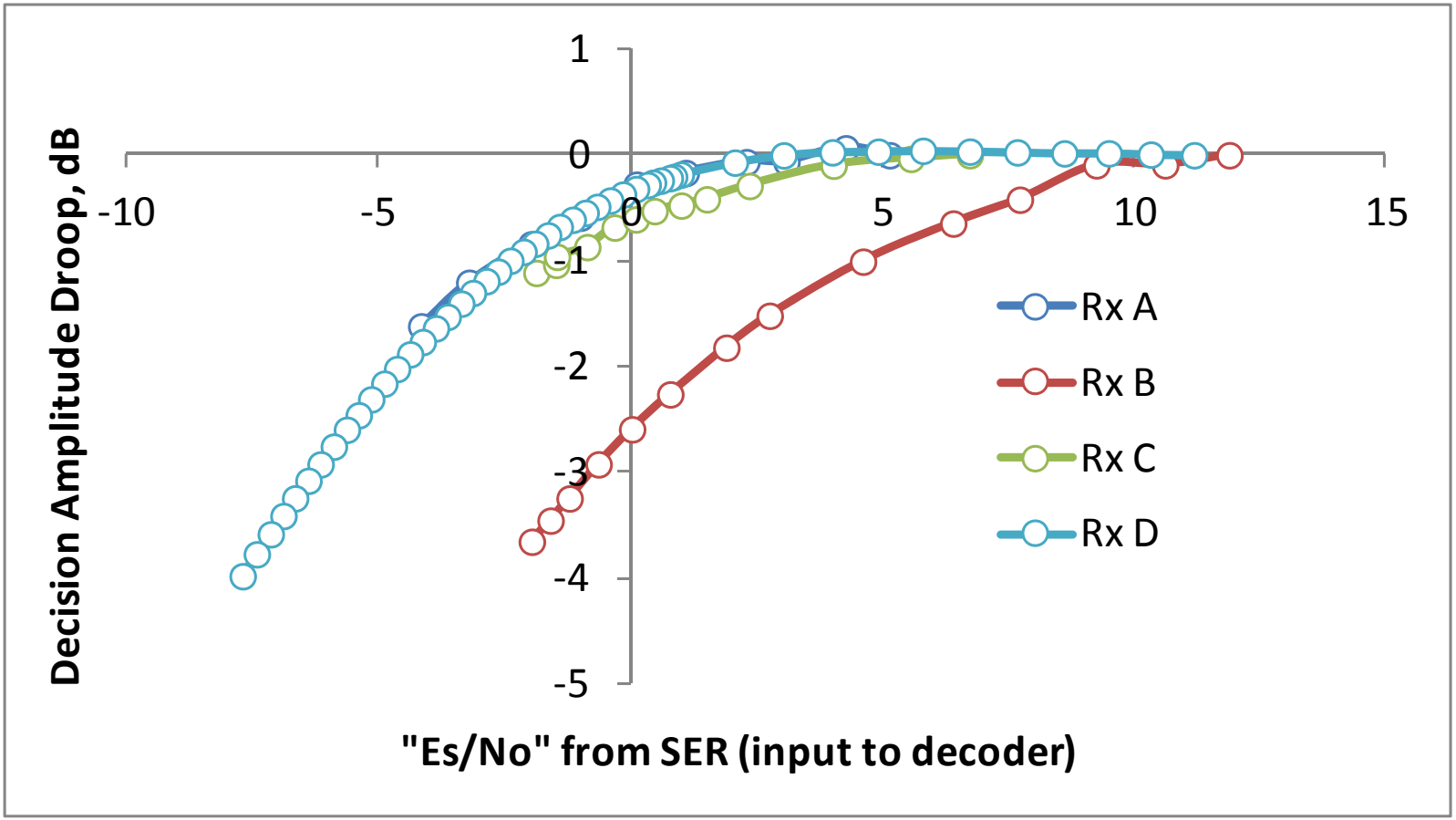




Data Logging

- Continuous Historical Record
  - Slips, rotations
  - Long runs
  - External triggers
- Publish on Demand
  - Configuration
  - BER and Es/No measurements
  - User notes

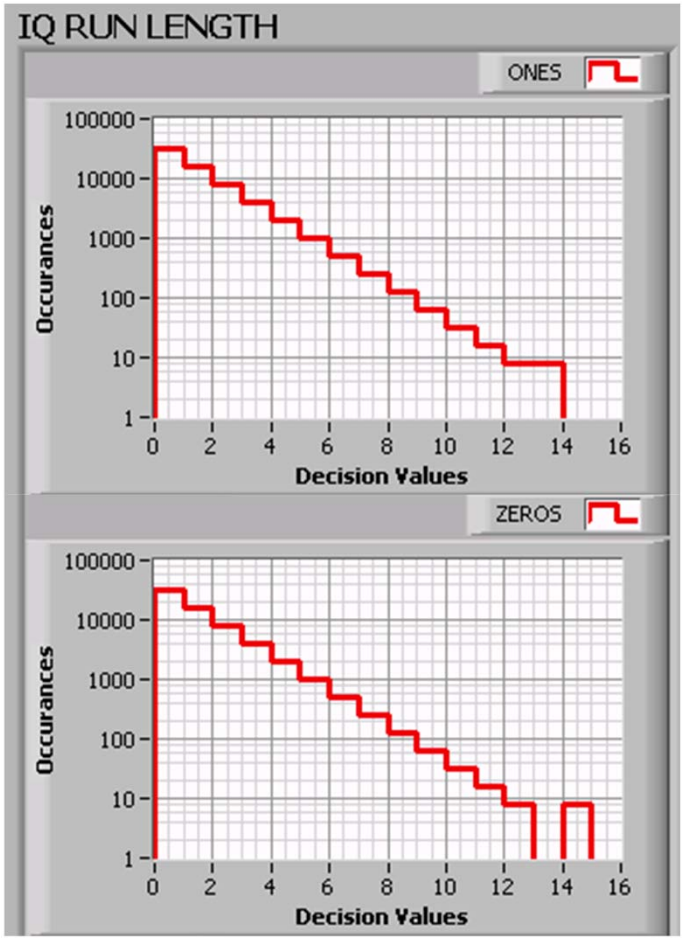
Data Reinvestigation



- Average symbol amplitude data taken from SER curves, plotted as amplitude droop

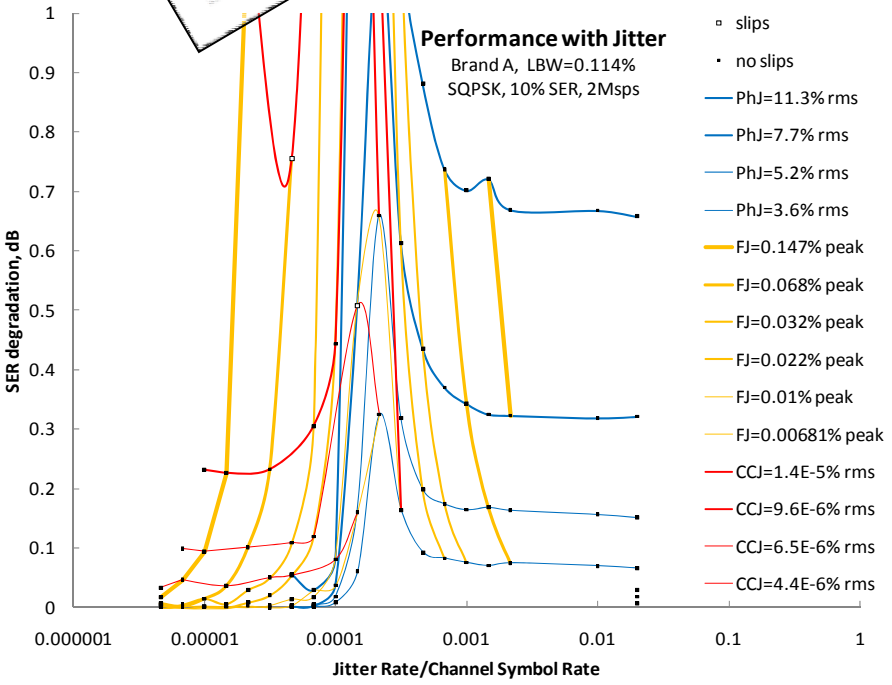
Supporting Measurements

- Run Lengths (2^{15}-1 pattern shown here)
- Discrete Programmable Test Points
  - Slips, rotations, long runs, clock phase lock, correlator lock, copy of data or clock…
  - General purpose test points with selectable functionality
- Channel Simulator



Sweeping Degradation From Baseline

Test Results,
Constant Jitter



Revised Model Results,
Constant Degradation

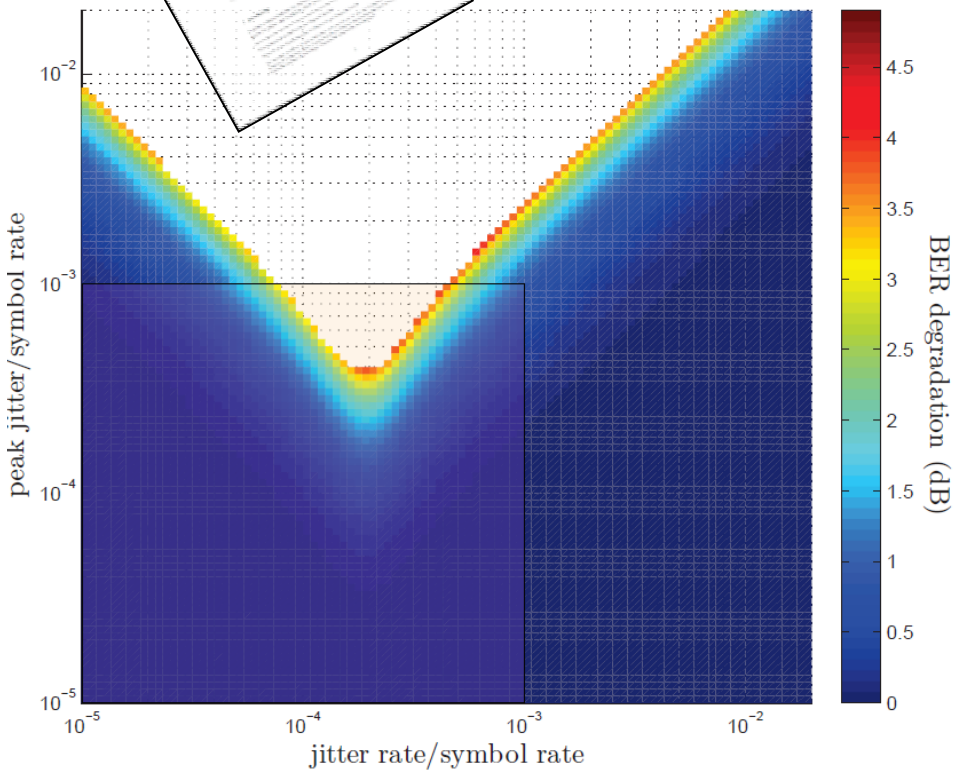
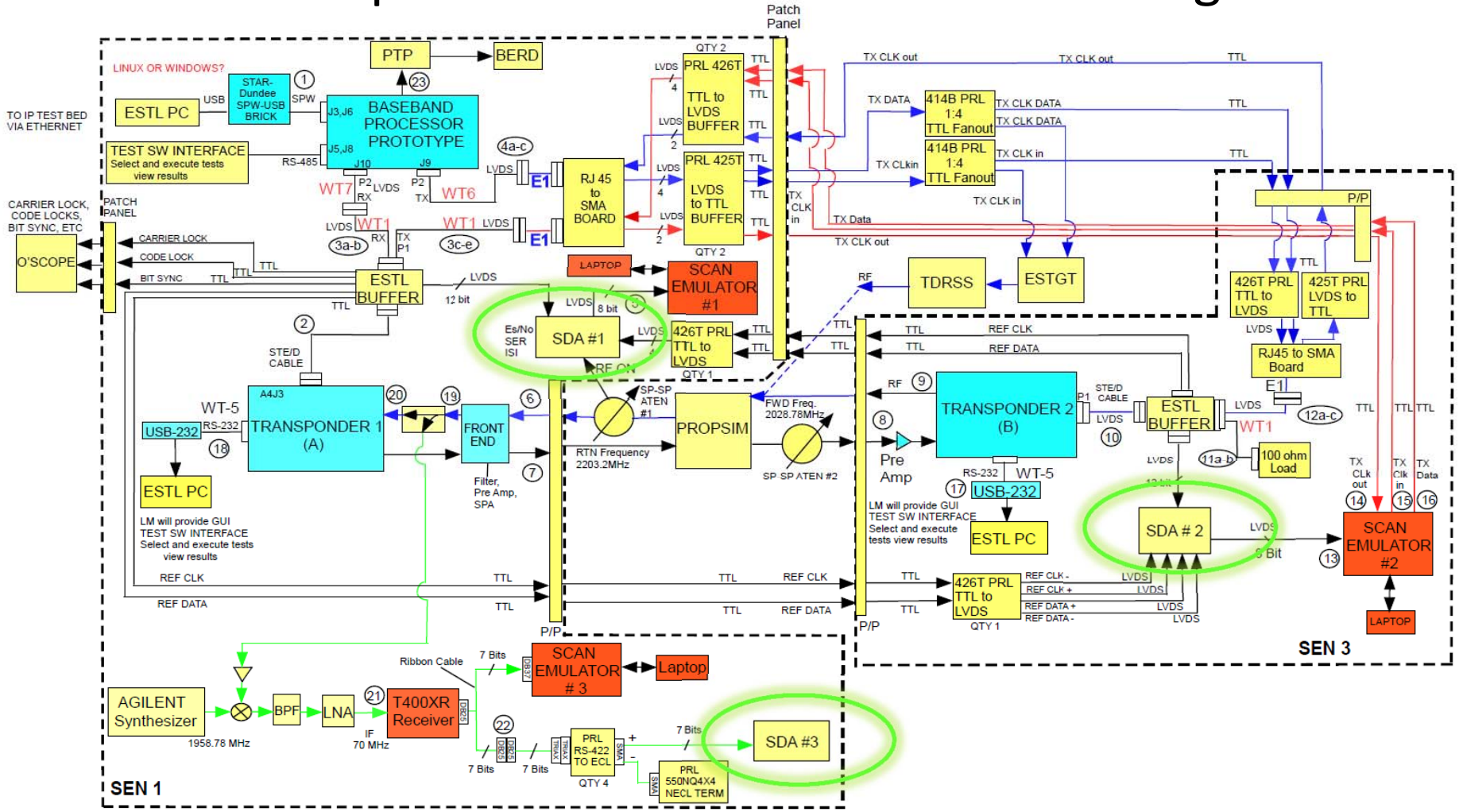


Figure 16. BER degradation surface plot as a function of peak jitter and jitter rate for $\zeta = 0.4$.

Use-Case Example

Orion Transponder – Baseband Processor Integration



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