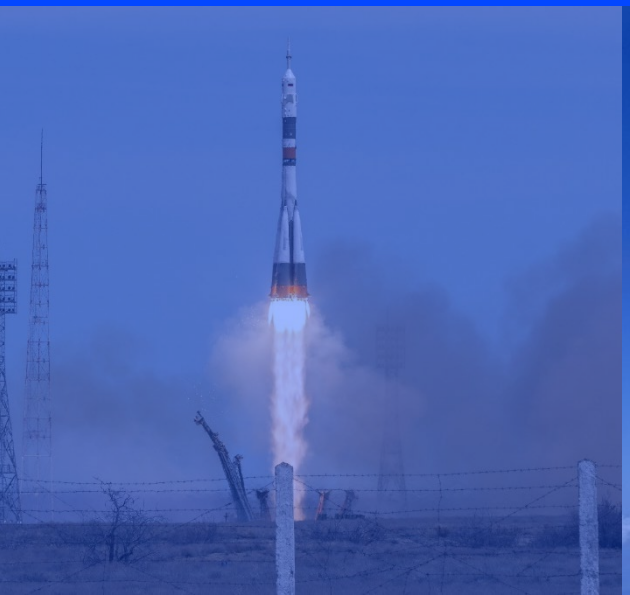
A DELTA INFORMATION SYSTEMS COMPANY

DATA QUALITY ESTIMATION (DQE)
The Two Main Techniques
Their Strengths and Weaknesses

By John R Carlson




PRESENTATION OVERVIEW

- Correlating Best Source Selectors
  - Data Quality Estimation is the Key
  - Combing Gain
  - Availability Gain
- Two Main DQE Methods
  - Bit-By-Bit, Signal Quality Based
  - Frame-By-Frame, Bit Error Probability Based
  - Performance Comparison
    - Overhead, Combing Gain ,Availability Gain, Dynamics
- Other Applications
  - Diversity Combining
  - Antenna Control
- Summary

CORRELATING BEST SOURCE SELECTOR

- Improves Signal Integrity using Spatial Diversity
- Processes Signals from Multiple Antennas/Receivers
  - After demodulation, bit synchronization, trellis processing, and error correction
- A BSS
  - Time Aligns Input Signals
  - Weights Aligned Signals by a Metric
  - Combines the Weighted, Aligned Signals
- Distinctions are
  - what metric, how often, how many bits.

- **A Proper Data Quality Estimate is the Key**

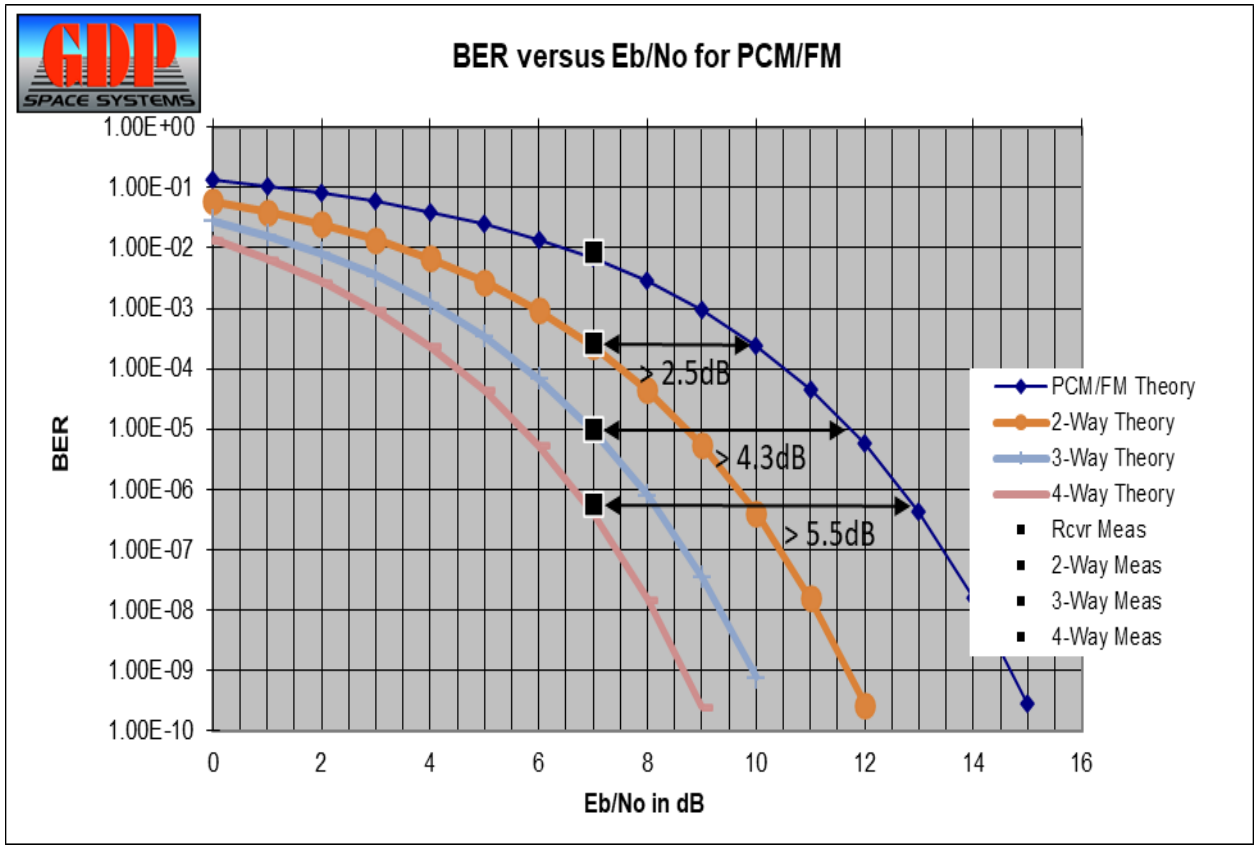
CORRELATING BEST SOURCE SELECTOR (cont)

- Without a BSS – Must Rerun the Test
  - Signal Lost During a Maneuver
- With a BSS – Don't Need to Rerun the Test
  - Saves Time – Days
  - Saves $$ - Beaucoup
  - Saves Environment – 6,350 kg less CO_2

- **BSS Improves Signal Integrity using Spatial Diversity**
  - **Combining Gain - Improved BER**
  - **Availability Gain - Fewer Outages**

BSS BENEFITS – Combining Gain

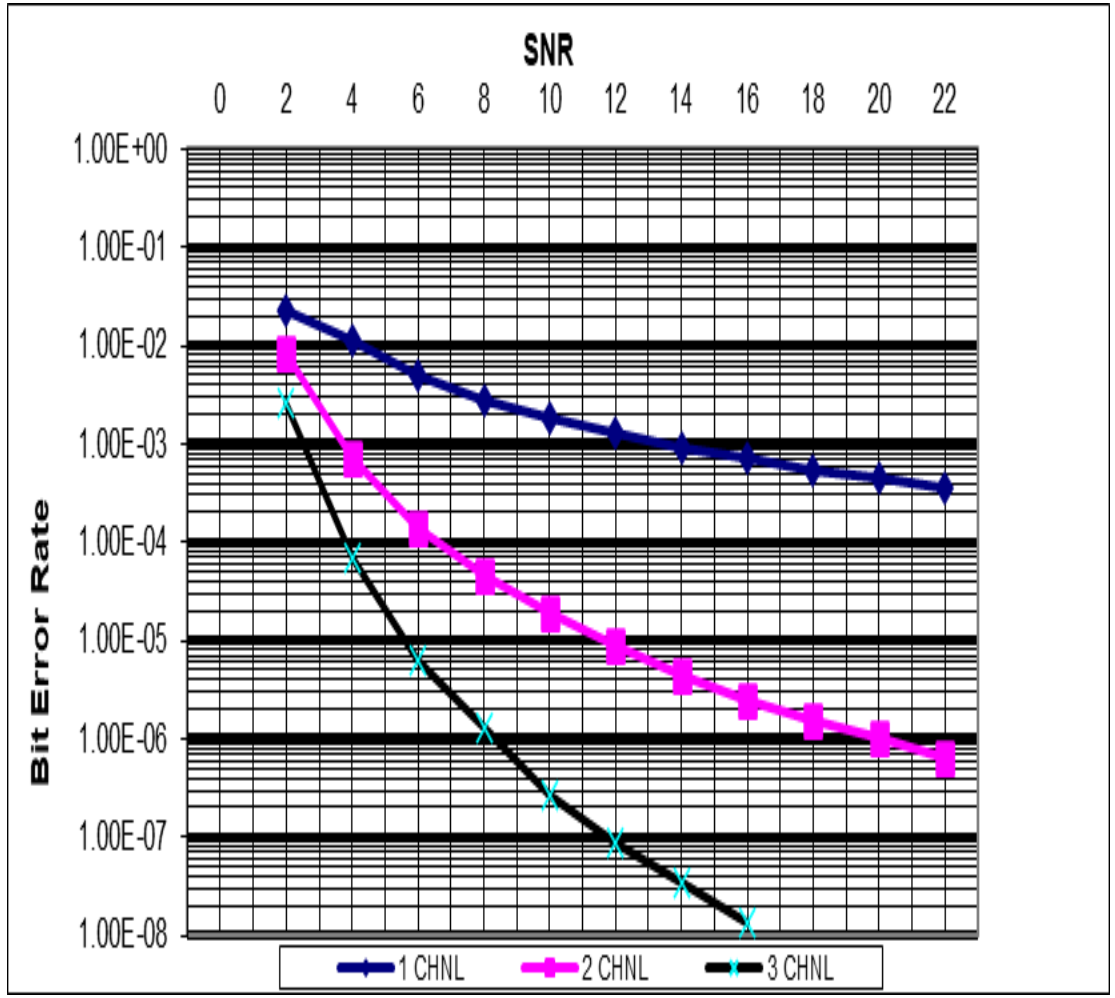
- Combing Gain
  - Double the number of signals
  - +3dB in SNR
- 6dB improvement
  - Doubles the antenna diameter
  - Increases the transmit power from 5W to 20W
  - Doubles range
- Combining implementation loss
  - Matching of the signals
  - Quantization and frequency of DQ bits



Measured Quad Combiner Combining Gain

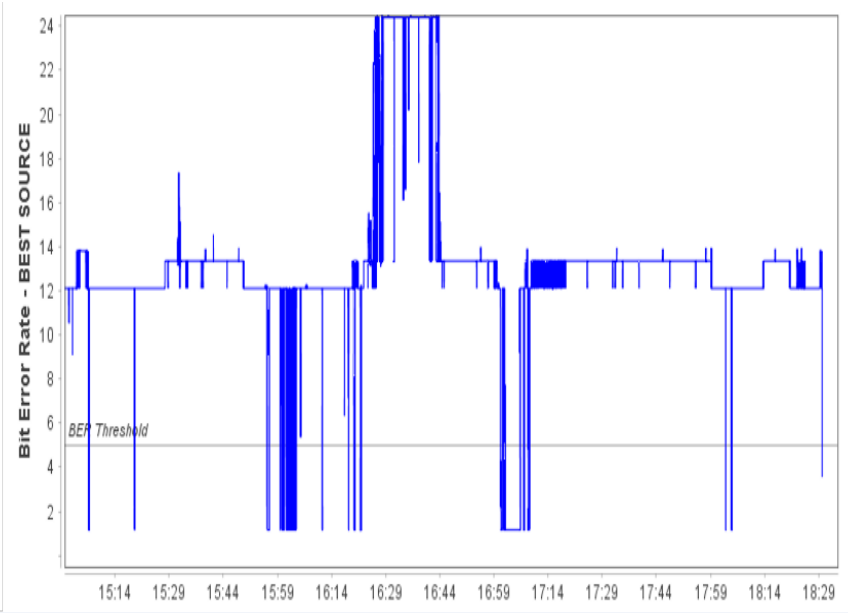
BSS BENEFITS – Availability Gain

- Availability Gain depends on
  - Statistics of the signal outages
  - Correlation between outages
- The figure shows the improvement in mission Bit-Error-Rate (BER) as the number of signals is increased
- Defining link availability as a BER greater than 10-5
- One received signal has a mission link availability of zero regardless of the received SNR
- Two signals the composite link is available for high SNRs
- Three signals it's available for all reasonable SNRs



BSS BENEFITS

- An actual automated report generated from a BSS illustrates the Availability Gain
- Figure shows BER of the Best Source
- Table shows how often a signal is Present (On-Deck), Time Aligned (Correlated), the Best Source, and Available (BER > 10-5)
- It shows, on the right, that link availability increases from 84% for the best individual signal to better then 96% for the composite signal



Group Summary / GRP1				
Input	Best Source	Correlated	On-Deck	Link Availability
CH01	3.01%	6.01%	100.00%	3.34%
CH02	49.27%	82.22%	99.16%	83.65%
CH03	16.54%	35.11%	97.86%	38.09%
CH04	31.18%	46.04%	100.00%	45.00%
Best Source	--	--	--	96.53%

THE DATA QUALITY ADVANTAGE

- Historical weighting metric
  - Signal level (AGC) or SNR
- **Biggest signal is not always the best signal**
- DQ the preferred weighting metric.
  - Includes signal distortion, interference and SNR
- The DQE should track signal dynamics

TWO MAIN DATA QUALITY ESTIMATION METHODS

- Bit-by-Bit (BBB) - PAX/GDP
  - DQ bit for each data bit
  - DQE is a direct measure of Signal Quality
  - 100% OH
- Frame-by-Frame (FBF) - RCC/IRIG
  - One 16 bit DQ word per 1k to 16k bit frame
  - DQE is a derived Bit Error Probability (BEP) estimate
  - DQE is average BEP estimate for the frame
  - <5% OH
- Interconnect Overhead
  - A concern for legacy cabled infrastructure
  - **Not a factor for modern Ethernet infrastructure**

COMBINING GAIN – Techniques

- Optimal Ratio Combining (ORC)
  - BBB with Soft (multi-bit) DQE
- Majority Vote (MV) – No DQE
  - if two of signals say a data bit is a ‘0’ and the third signal says the data bit is a ‘1’, the majority decides that the data bit is a ‘0’
- Weighted Majority Vote (WMV)
  - signals are weighted by their DQ so the votes from low DQ signals don’t count
  - BBB WMV uses 1-bit DQ per Data Bit
  - FBF WMV uses the average DQ for the frame
- Two signal Combining Gain – Only BBB
- More than two signals – BBB or FBF

COMBINING GAIN – Performance Comparison

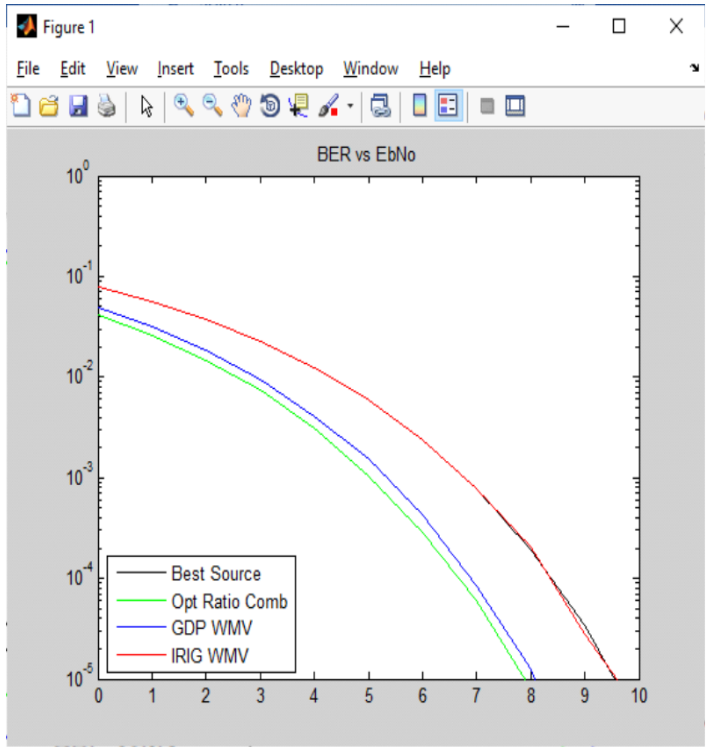


Figure 5a - BER for 2 Signals
$E_bN_{01} - E_bN_{02} = 3\text{dB}$

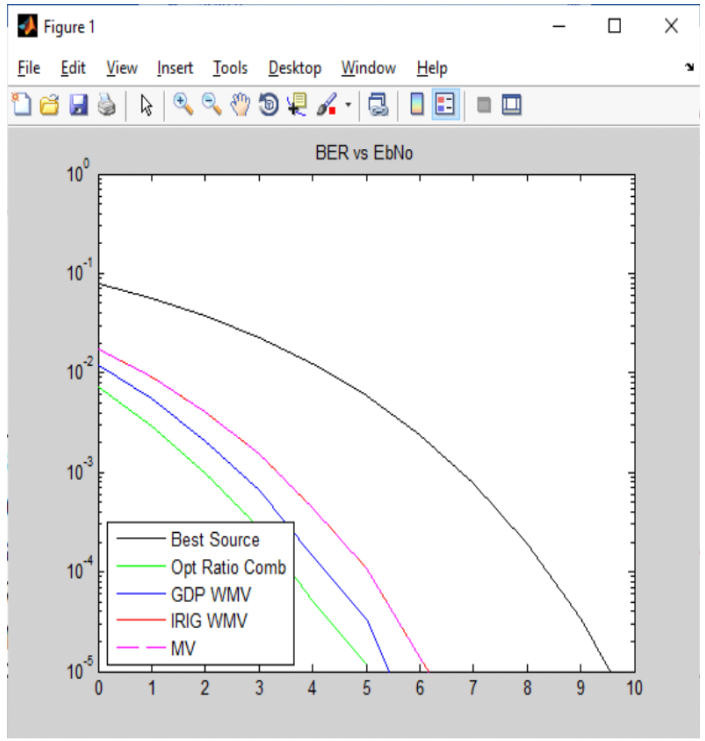


Figure 5b - BER for 3 Signals
$E_bN_{01} = E_bN_{02} = E_bN_{03}$

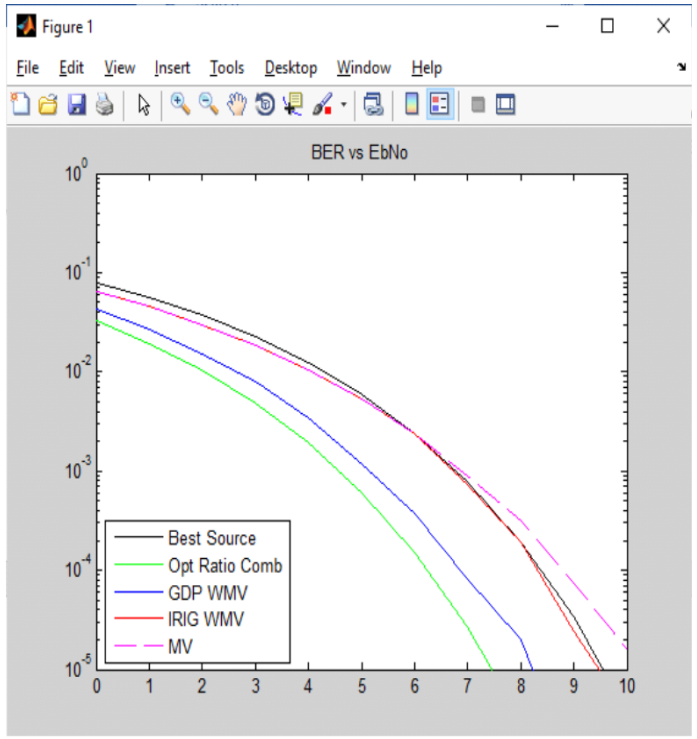


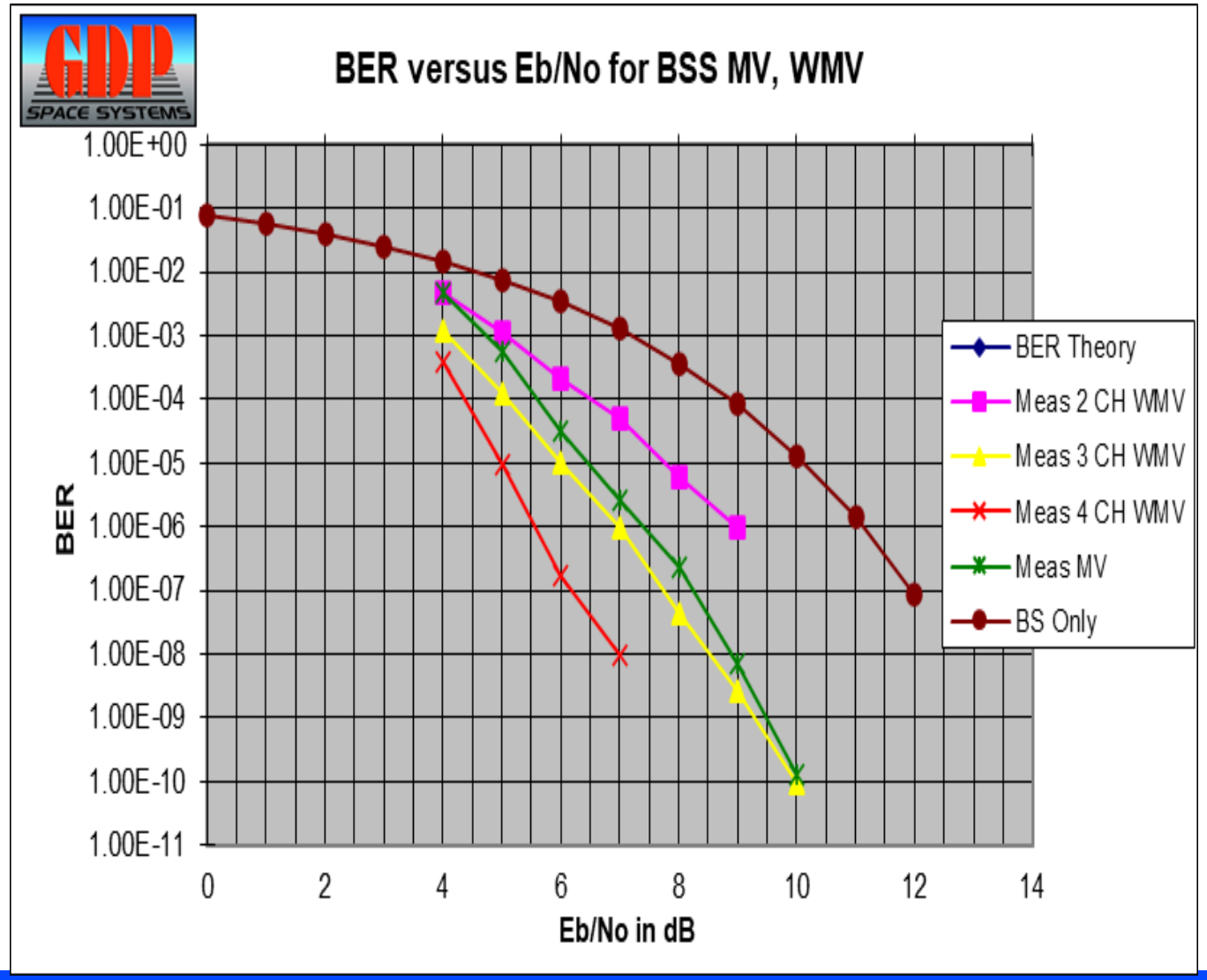
Figure 5c - BER for 3 Signals
$E_bN_{01} - E_bN_{02} = E_bN_{01} - E_bN_{03} = 4.5\text{dB}$

COMBINING GAIN – Performance Comparison (cont)

- For 2 signals, one with a 3dB worse EbNo
  - ORC provides over 1.5dB
  - BBB WMV provides nearly 1.5dB
  - FBF WMV is equal to the BS
- For 3 signals with equal power
  - ORC provides over 4.5dB
  - BBB WMV provides 4dB
  - FBF WMV is equal to MV providing about 3.5dB gain over the BS
- For 3 signals, two with 4.5dB worse EbNo
  - ORC provides around 2dB
  - BBB WMV provides around 1dB
  - FBF WMV is equal to and provides no gain over the BS
  - MV is worse than the BS
- **BBB WMV is best, followed by FBF WMV, MV, and last straight BS**

COMBINING GAIN – Measured Performance

- Measured BSS performance
- BBB WMV provides the expected gain of about 5+dB for 4 signals, 4dB for 3 signals and 2+dB for 2 signals
- Straight MV provides 3.5dB for 3 signals
- Although not shown in the figure MV provides no gain for 2 signals
- MV provides no improvement for 4 signals over 3 signals.



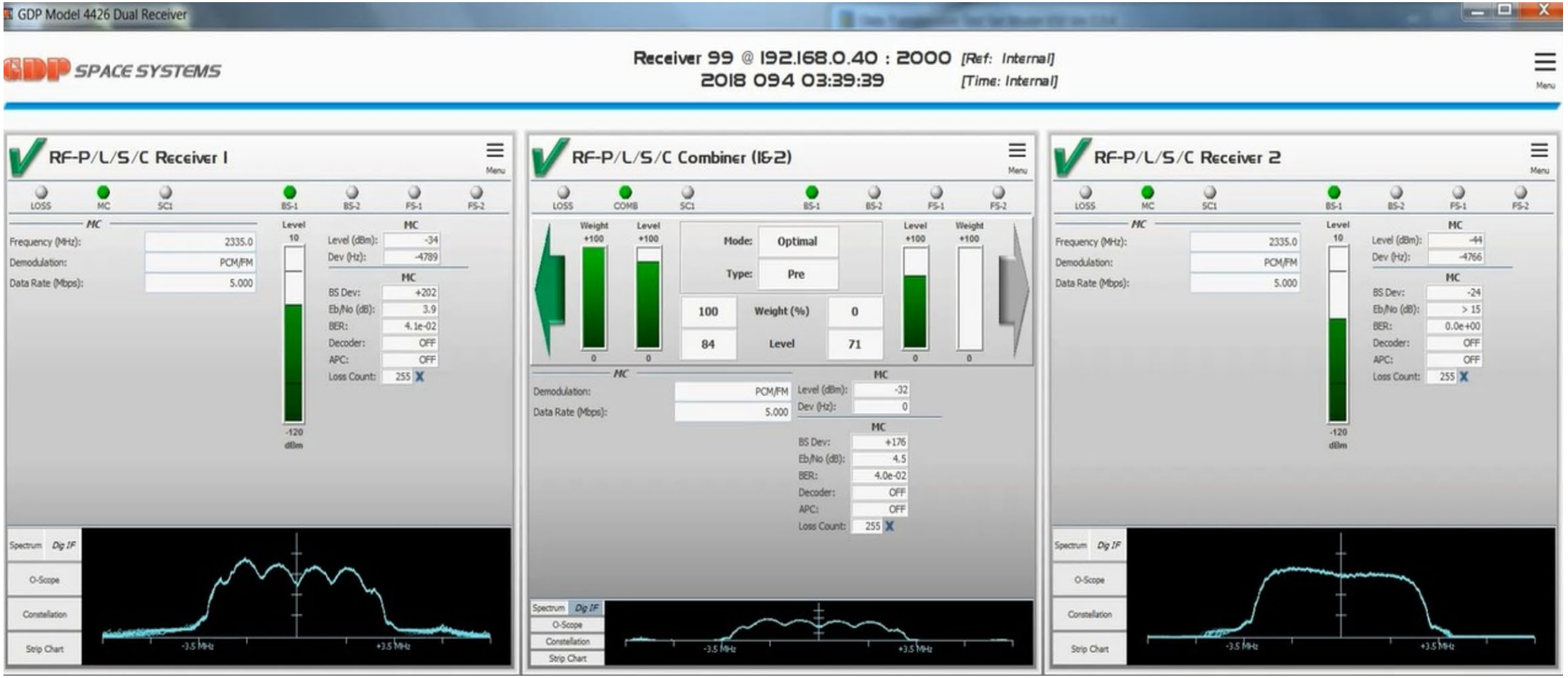
SIGNAL DYNAMICS

- A BSS aligns signals with differential delays
  - When a signal is added or dropped, relative delays are recalculated and readjusted
  - Realignment negatively affects the BSS response time
- BSS Break Frequency (wo realignment)
  - BBB > 33kHz
  - FBF < 5kHz, 1k frame @5Mbps.
- BSS Realignment
  - Acquisition ~ 1.25kHz + DQ update rate
  - Hold, DQ update rate
  - Realignment, search dependent
- For 2 Signals, acquisition is limiting factor
- For More than 2 Signals, Break Frequency dominates
- **For Dynamics BBB is Superior to FBF**

DIVERSITY COMBING

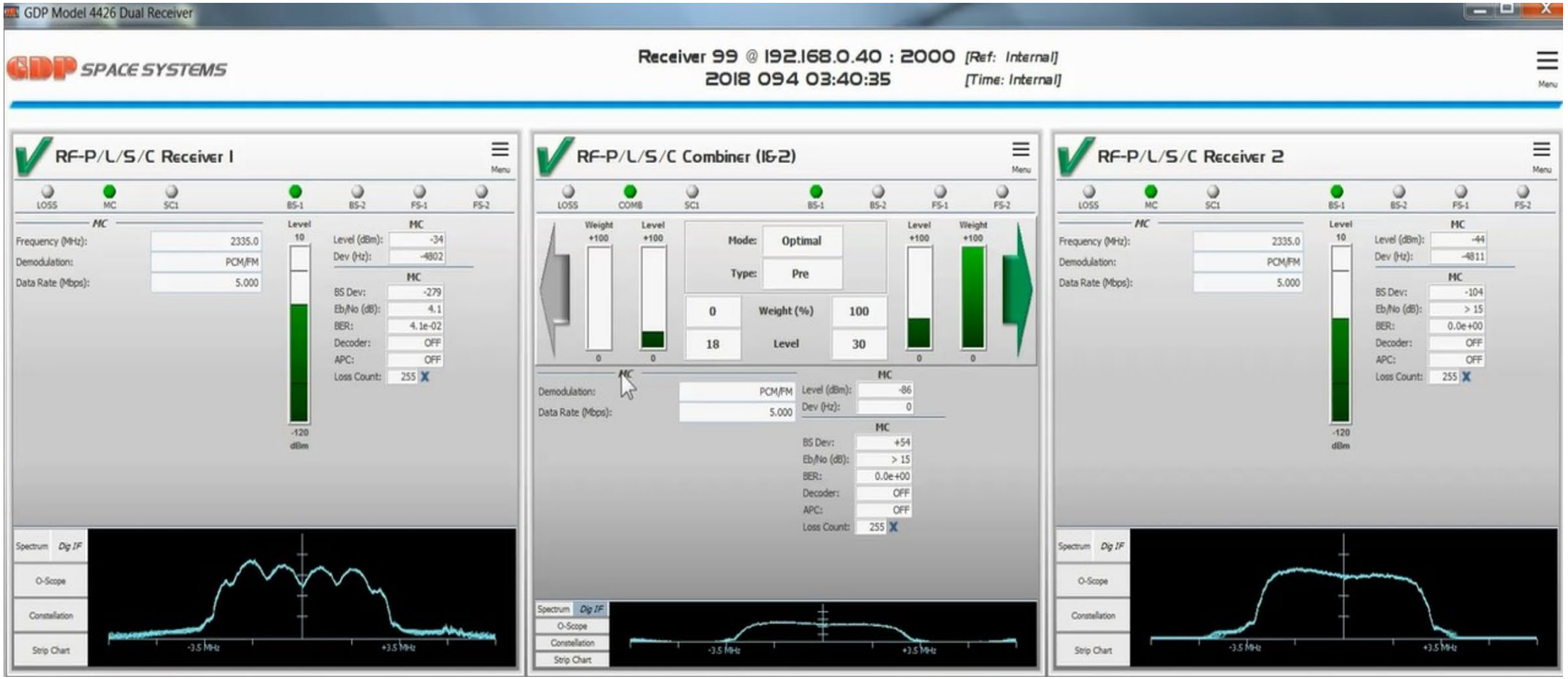
- Historically Diversity Combiners have used
  - Signal level (AGC) or SNR as the weighting metric
- **Biggest signal is not always the best signal**
- DQ is a Superior weighting metric.
  - Includes signal distortion, interference and SNR
- DQE should track signal dynamics

DIVERSITY COMBINING – The DQ Advantage (cont)



Using the AGC/SNR metric the bad signal is weighted at 100%, resulting in a 4*10-2 BER for the combiner

DIVERSITY COMBINING – The DQ Advantage (cont)



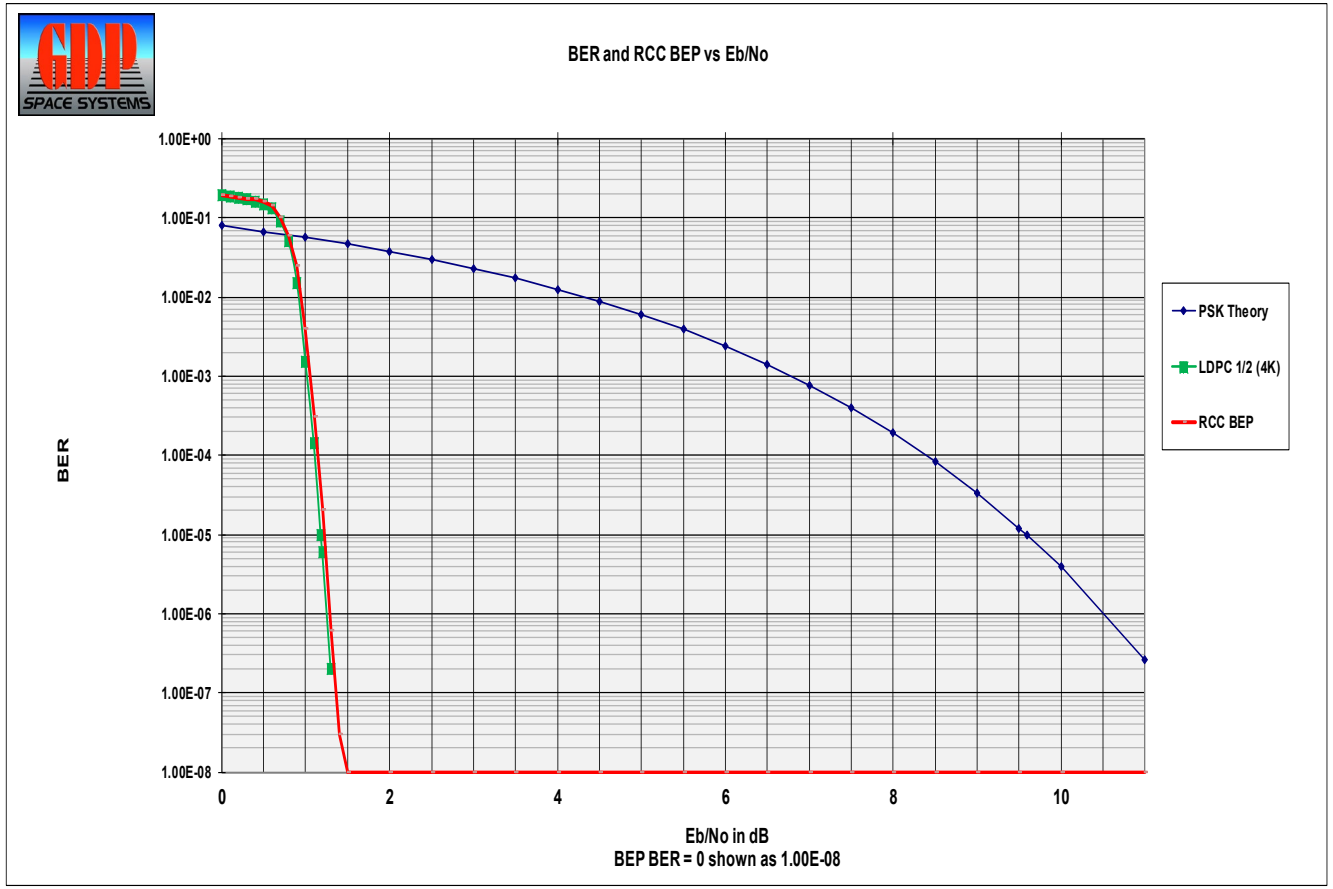
Using the DQ metric the good signal is weighted at 100%, resulting in an error free combiner

ANTENNA TRACKING

- Historically Antenna Control Units have used
  - Signal level (AGC) or SNR to select the signal to track
- Biggest signal is not always the best signal to track
- **DQ is a Superior Tracking Metric.**
  - Includes signal distortion, interference and SNR
  - Avoids tracking multipath or interference
- For multiple signals from a single target
  - True Signal Quality Based DQE
  - Not Derived DQE like BEP
- **A Signal Quality Based DQE selects an ACU Control that is**
  - **Less prone to Dropouts**
  - **Has a Superior SNR**

ANTENNA TRACKING(cont)

- Signal 1, R1/2 LDPC Encoded QPSK
- Signal 2, Uncoded QPSK
- At EbNo = 3dB the RCC BEP = 0 for the encoded signal
- At EbNo = 7dB the RCC BEP = $4x10^{-6}$ for the uncoded signal
- The encoded signal has a better BEP but a worse signal quality and is much closer to its loss threshold
- An RCC BEP based DQE incorrectly declares the encoded signal as the best signal
- **A Signal Quality Based DQE Selects the Better-Quality Signal for ACU Control**



Encoded and Uncoded BER & BEP vs EbNo

SUMMARY

BBB DQ vs FBF BEP Performance		
PERFORMANCE MEASURE	**BBB DQ**	**FBF BEP**
Overhead	**100%**	**<5%**
BSS Static Performance		
Combining Gain (2 Signals)	**Yes**	**No**
Combining Gain (>2 Signals)	**Yes**	**Limited to BS or MV Performance**
Availability Gain	**Yes**	**Yes**
BSS Dynamic Performance		
Combining Gain	**Fast**	**Limited By Frame Rate**
Availability Gain	**Limited by Acq. Time**	**Limited By Frame Rate**
Diversity Combiner	**Yes**	**Limited to BS**
Antenna Control		
Polarization	**Yes**	**Yes**
Multiple Signals	**Yes**	**No**

QUESTIONS?

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