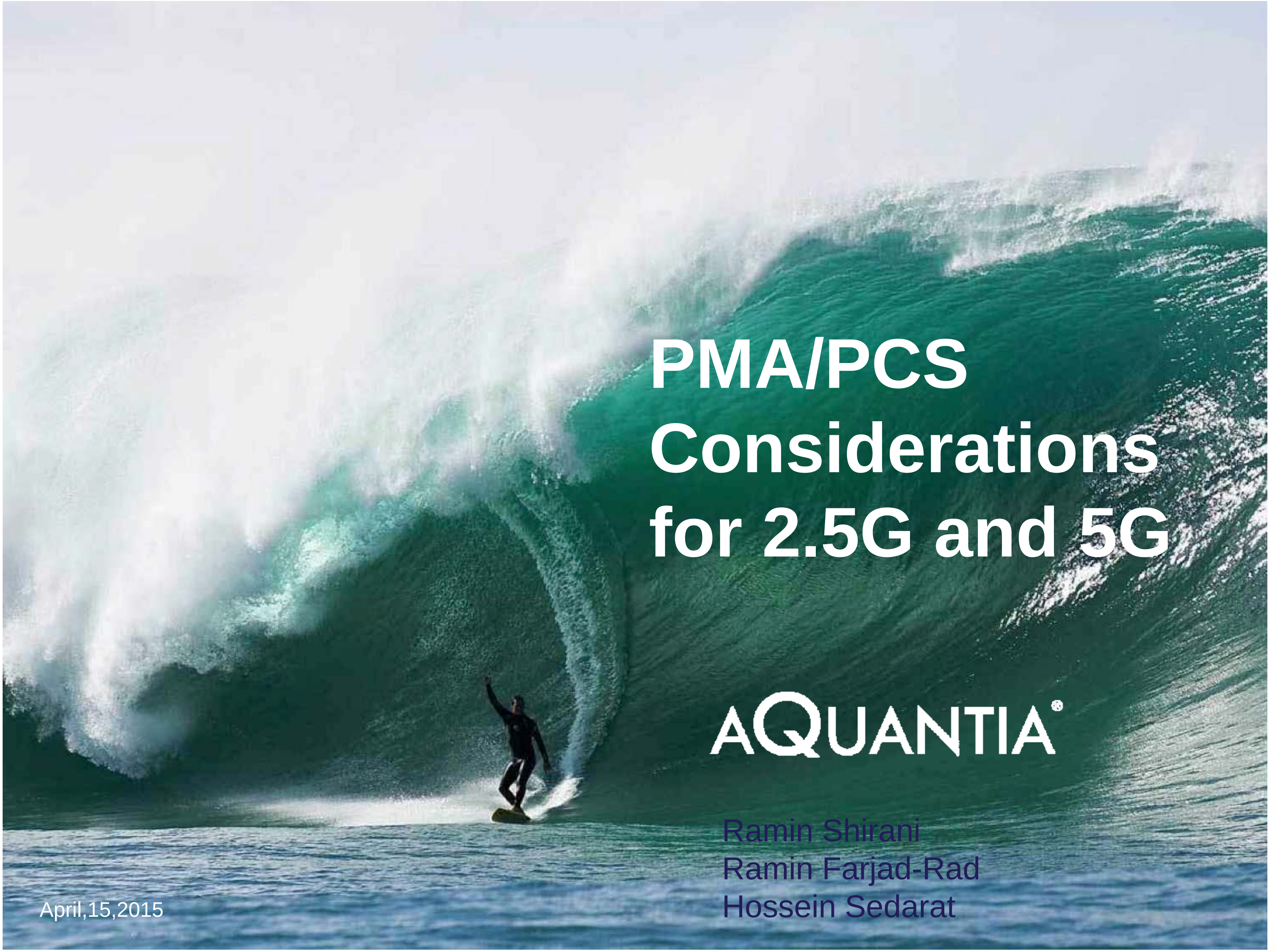

PMA/PCS Considerations for 2.5G and 5G

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Ramin Shirani
Ramin Farjad-Rad
Hossein Sedarat

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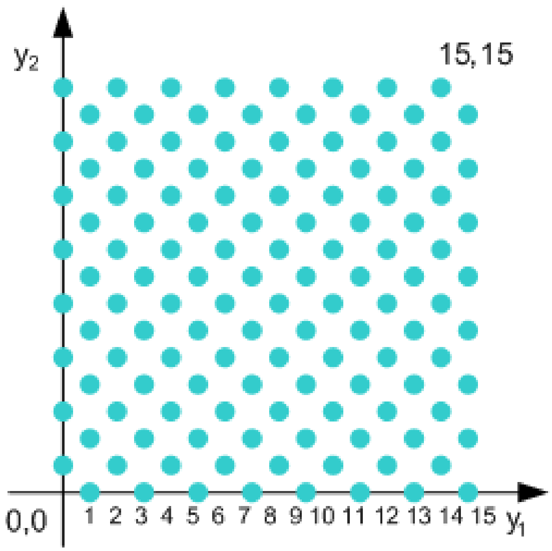
10GBase-T Overview

- 10.00 Gbps over 4 pairs
- Effective rate per pair = 2.5Gbps
- Symbol rate per pair = 800 MSymbols / second
- PAM 16 signaling is used
  - PAM 16 = 4 bits per symbol
  - 8 bits per 2 symbols are possible
  - Actual implementation is 7 bits over 2 symbols

10Gbase-T Constellation

- Out of the 256 (2^8) possible combinations of two symbols, only 128 are allowed
- (128 = 2**7 represents 7 bits)

- This scheme is called DSQ128 “Double Square 128”



The 128 allowed combinations
For example, (15,15) is not allowed. That means if you send level 15 on a pair, the next level you send on this pair can’t be level 15 for the two symbol sequence y1, y2

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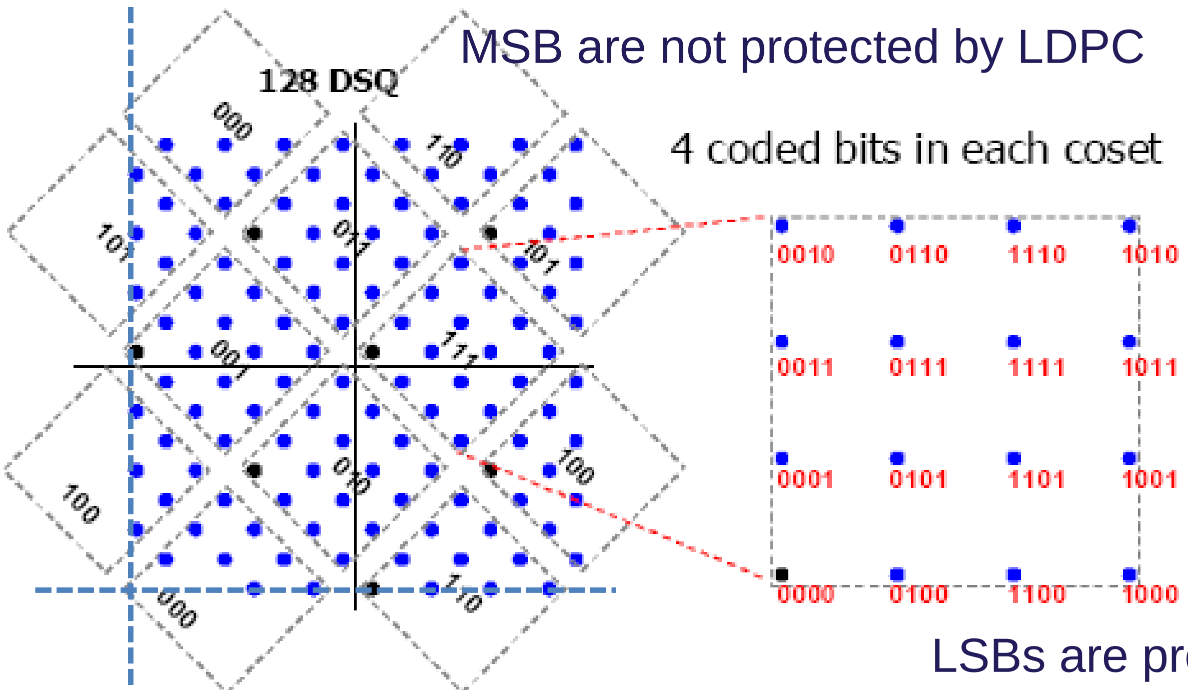
DSQ 128 – Detailed view

MSB are not protected by LDPC

4 coded bits in each coset



LSBs are protected by LDPC

3 uncoded bits per coset

ESD impulse noise can corrupt MSBs that lack LDPC protection (more to come)

How Can we protect MSBs with LDPC?

- Use PAM 16 signaling per symbol
  - PAM 16 = 4 bits per symbol
  - 8 bits per 2 symbols
  - All 8 bits over 2 symbols are used
  - 325 of additional bits are used for protecting previously un-coded bits
  - 97 bits are set to zero (known transmitted bits help LDPC gain)
  - Combination of LSB & MSB bits in the LDPC Frame together the *a priori* known 97 bits improves LDPC gain by over 1dB

- All bits are protected by LDPC

- Robust to Impulse non-stationary noise

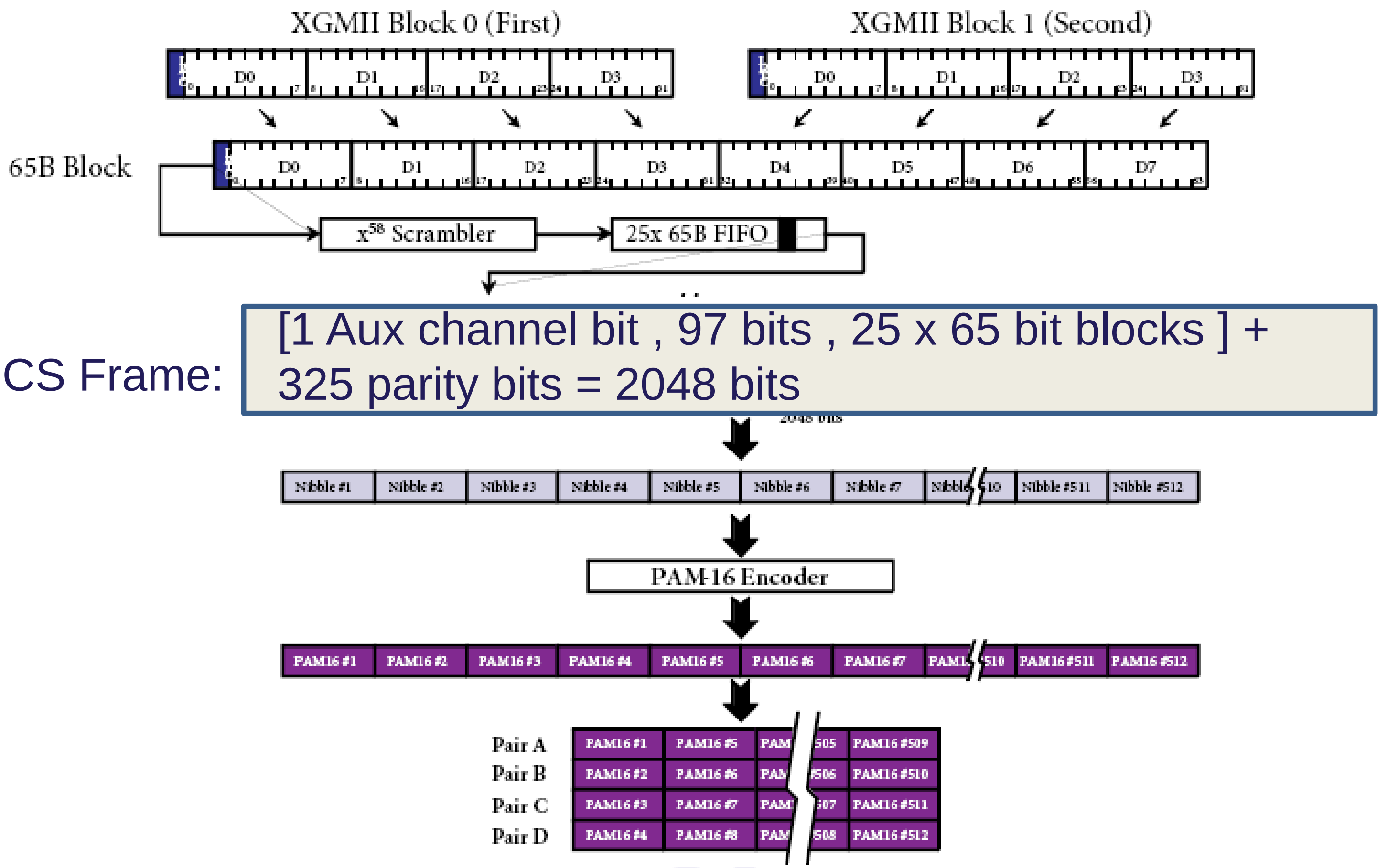
- Otherwise, a scaled version of 10GBase-T

- All other electrical specs are scaled versions of 10GBase-T
  - Minor enhancement is total transmit power: 1.0 to 3.0 dBm
    - 2.2 dB below 10GBASE-T bounds to limit emission on CAT5e while still allows good SNR

Modulation and Encoding

- 5Gb/s via fully LDPC coded PAM 16 running at 400Ms/s
- 2.5Gb/s via fully LDPC coded PAM 16 running at 200Ms/s
- LDPC Frames
  - 5G = 320ns
  - 2.5G = 640ns
- Training is the same as 10GBASE-T training sequence at 400 MS/s and 200 MS/s

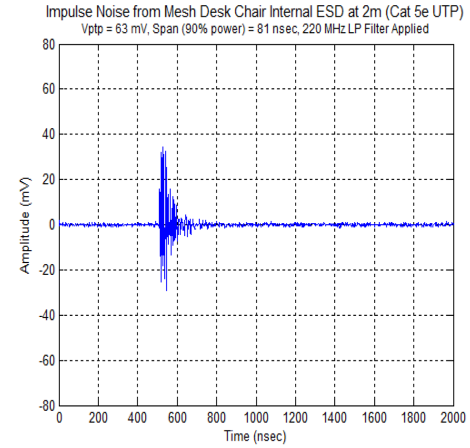
Frame structure



PCS Frame: [1 Aux channel bit , 97 bits , 25 x 65 bit blocks] + 325 parity bits = 2048 bits

- Follows 10GBase-T XGMII → 64b/65b → Scrambling (master/slave)
- PCS frame adjusted to accommodate all bit encoding
  - 320ns @ 5Gb/s ; 640ns @ 2.5Gb/s
- PAM encoder(Grey Coded PAM-16) → THP → Lane Transmission

Impulse Noise Learnings



Example of ESD Differential noise in enterprise

- Frequent impulse noise interference events can increase the bit error rate of an otherwise properly operating data link above specified limits

- Low-level ESD events are generally band pass (80MHz to 200 MHz), low duration, frequent in enterprise and can interfere with the operation of newer high-speed data links in the enterprise environment
  - Example of public library enterprise space with hundreds of events per hour

- EFT impulse noise due to switch contact arcs are generally lower in frequency (< 50MHz) and long in duration, but very infrequent

- Created an Impulse Noise Immunity Simulation Model with focus on the ESD impulse noise as the relevant enterprise noise component

- Passed captured ESD data through the 128-DSQ system in parallel to a fully encoded PAM16 system and measured robustness

Observations of PAM16 Performance from Simulations

- PAM16 provides good margin for ESD impulse at both 5G and 2.5G data rate on cat5e and cat6
  - Standing up from desk chair once can generate multiple impulse noise events over a 10-second time span
  - Desk chair internal ESD has a band-pass shaped spectral frequency content; appears as short spikes in the time domain which are more favorable to PAM16 coding

- PAM16 provides good margin for ESD-based impulse noise on Cat 5e screened cable
  - Cat 5e screened cable provides excellent alien crosstalk suppression, but EM immunity characteristics are often degraded (and uncontrolled) above 100 MHz
  - Has “highpass” ingress coupling which creates short-duration impulse noise spikes

- PAM16 should provide better impulse noise immunity in the enterprise environment for frequent ESD-based impulse noise especially when the relative humidity is low (fairly common)


Appendix
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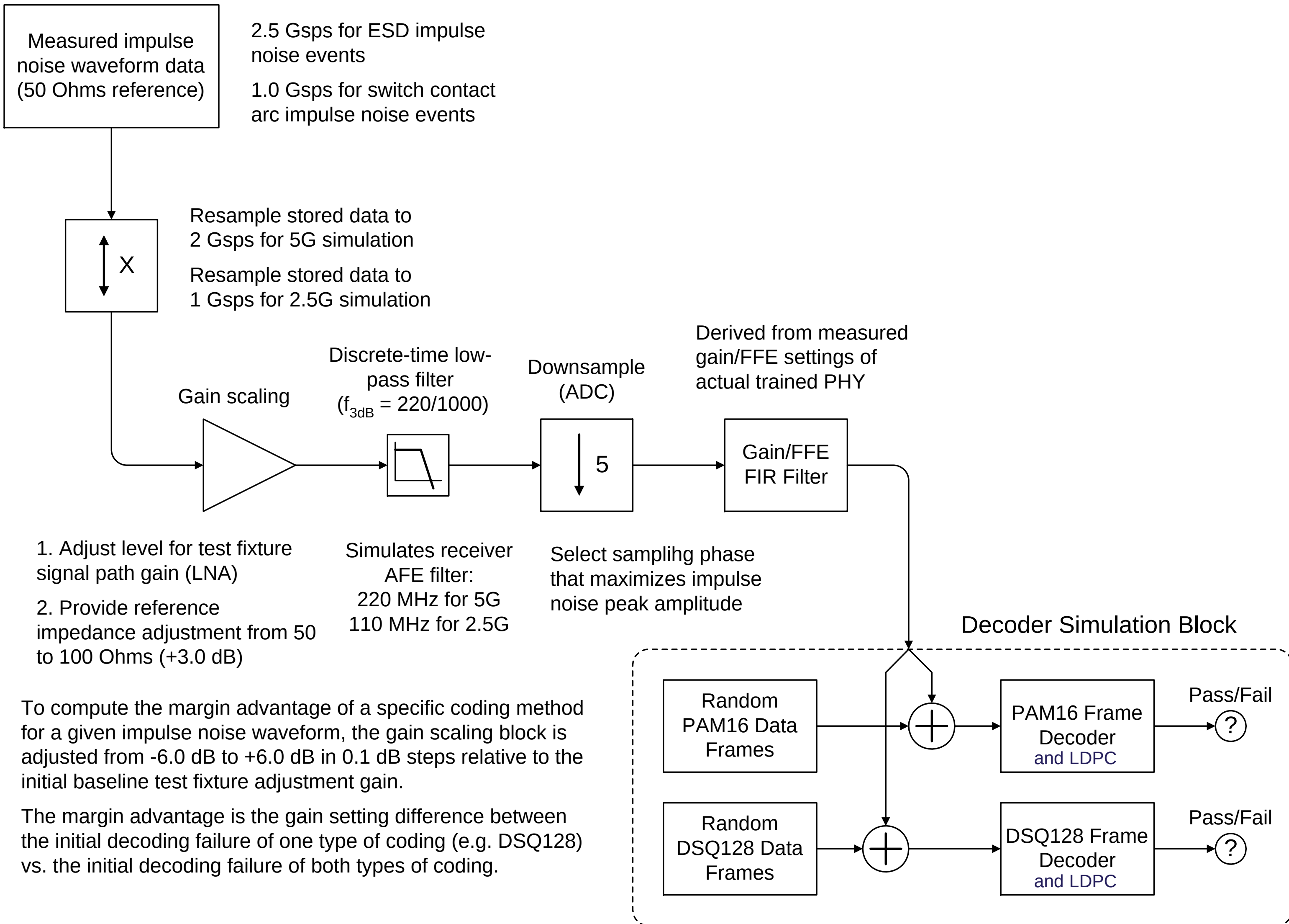
Flow Diagram of Impulse Noise Immunity Simulation Procedure



To compute the margin advantage of a specific coding method for a given impulse noise waveform, the gain scaling block is adjusted from -6.0 dB to +6.0 dB in 0.1 dB steps relative to the initial baseline test fixture adjustment gain.

The margin advantage is the gain setting difference between the initial decoding failure of one type of coding (e.g. DSQ128) vs. the initial decoding failure of both types of coding.

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33 Example simulations for PAM16 with Real-World ESD Impulse Noise Waveforms

	Cat 5e UTP		Cat 6 UTP		Cat 5e ScTP	
Description of Event	5G PAM16 Advantage (dB)	2.5G PAM16 Advantage (dB)	5G PAM16 Advantage (dB)	2.5G PAM16 Advantage (dB)	5G PAM16 Advantage (dB)	2.5G PAM16 Advantage (dB)
Tool contact at 50 cm holding tool metal after walking on carpet	4.7	8.2	4.7		7.1	
Tool contact at 50 cm holding tool metal after standing up from guest chair	4.2	6.1	2.0			
Tool contact at 100 cm holding tool metal after walking on carpet	4.9		5.9			
Tool contact at 100 cm holding tool metal after standing up from guest chair	3.7	4.5	5.4		7.4	
Standing up from and discharge to guest chair frame by hand contact at 100 cm	3.2	3.3	3.0	1.0		
Standing up from and discharge to guest chair frame by tool contact at 100 cm	3.7	3.7	8.2	8.2		7.8
Tool contact to whiteboard shelf at 150 cm holding tool metal after standing up from guest chair	3.6		3.6	6.9		
Mesh desk chair internal ESD at 1m	7.6	6.9	6.1	4.9	6.8	
Mesh desk chair internal ESD at 2m	3.5		5.3		6.5	

- Focus was Cat5e UTP due to rich set of data collected before