PAM2 to PAM4 Transition in the Training

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Key issues

- For both TD and ACT methods, the 10G training symbol is PAM2 while the data mode symbol is PAM4
- Transitioning from PAM2 to PAM4 adds extra steps and complexity
- If a unified sequence is used among the rates, this complexity “trickles down” into 2.5G/5G training
- Two approaches:

  A) Separate training sequences per rate

  B) Same training sequences for all rates, but train 10G with PAM4 symbols

ACT proposed training

- Extra complexity:
  - COUNTDOWN is the extra state in the training to move from PAM2 and PAM4 training
- Most of training is done with PAM2, not the intended modulation in the data mode (PAM4)
- An extra step for 2.5G/5G training

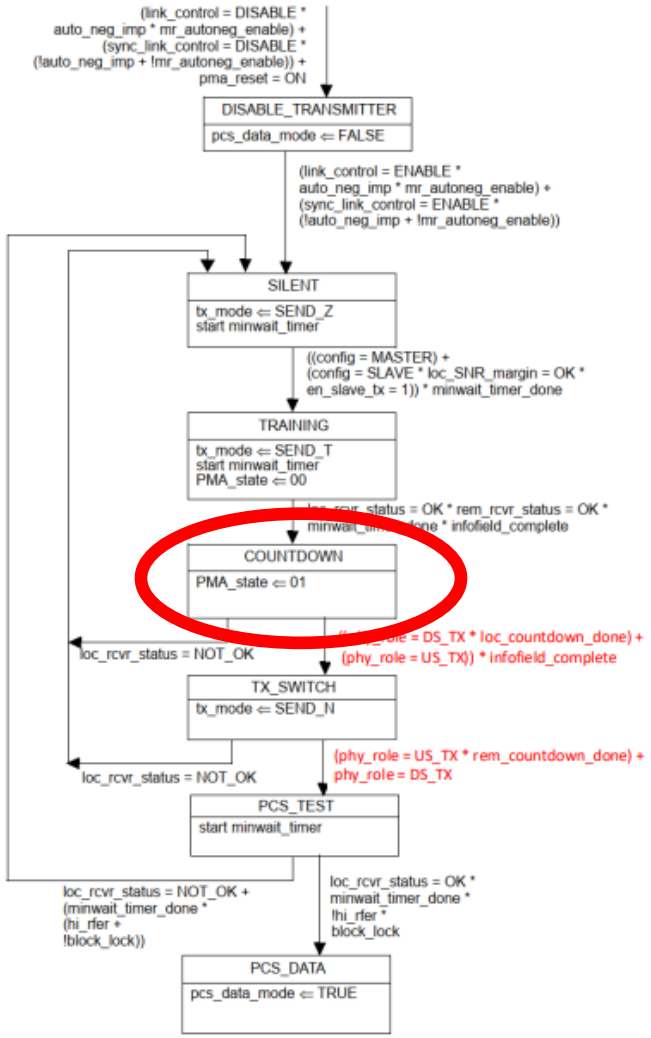


Figure 149–32—PHY Control state diagram

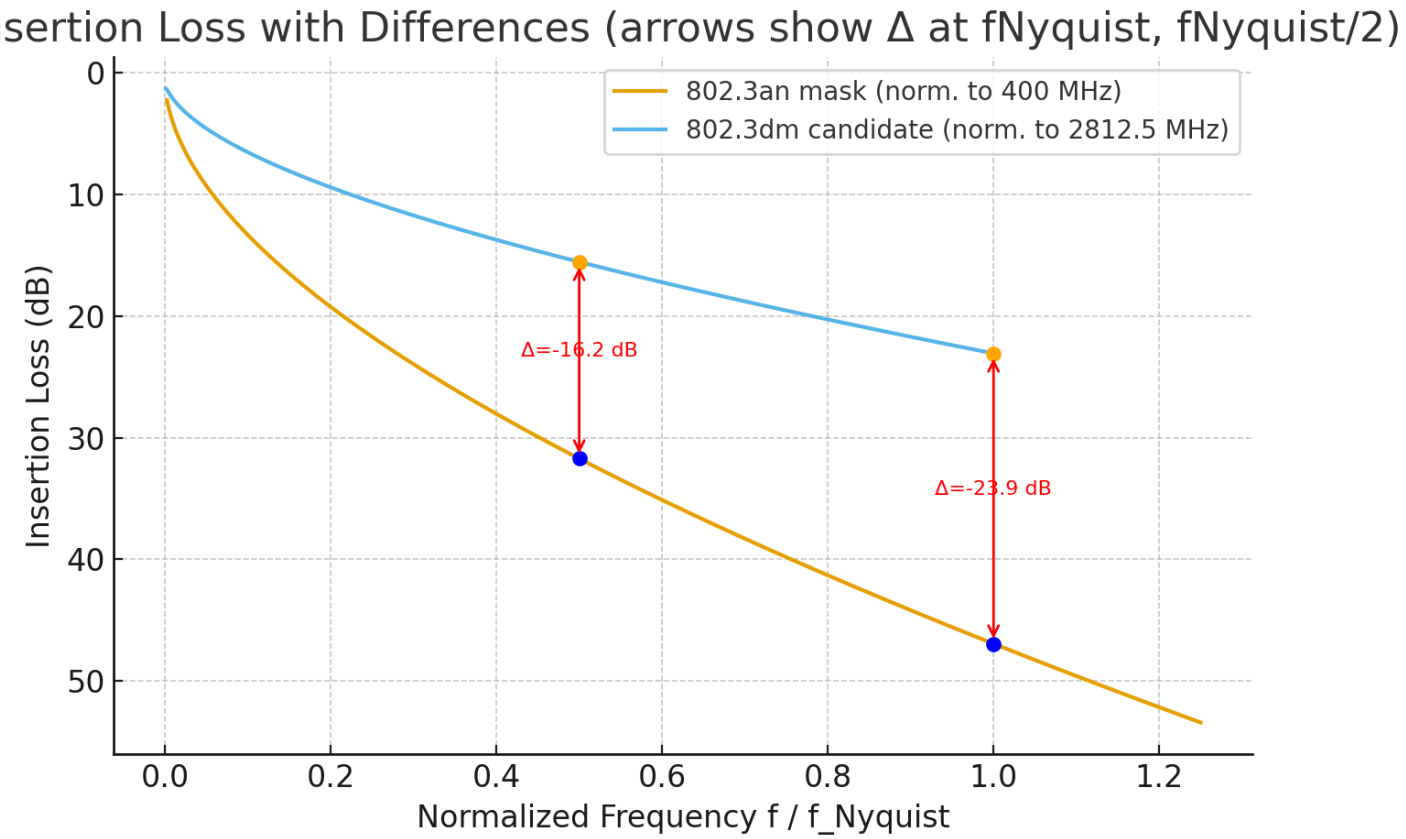
Option A: Separate trainings for lower rates and 10G

- Solution:
  - Separate simpler training sequence for 2.5G/5G;
- Pros:
  - Optimized robustness and simplicity at 2.5G/5G (no PAM mode transition inside training)
  - Minimizes risk for established 2.5G/5G interoperability
- Cons:
  - Two state diagrams to maintain and validate
  - Larger firmware/RTL footprint; higher verification/QA effort
  - Potential for divergence over time, increasing maintenance costs

Option B : Use PAM4 for 10G training

- Solution:
  - Start 10G training with PAM4 symbols for 10G;
- Pros:
  - One state machine across 2.5G/5G/10G, maximizing reuse
  - Eliminates the PAM2-to-PAM4 mid-training transition at 10G
- Cons:
  - Early PAM4 training is more challenging: d_{min} is 3 times higher from PAM2 compared with PAM4

PAM4: Feasible and proven



- Compared to 802.3an (10GBASE-T), which used PAM2 for training, 802.3dm offers much greater margin
- This is not new: IEEE 802.3ck electrical backplane and direct-attach copper PHYs

Conclusion

- Problem:
  - PAM2→PAM4 transition in 10G adds steps;
  - A unified state diagram pushes this complexity into 2.5G/5G.
- Solution: Train 10G directly in PAM4; use one state machine across 2.5G/5G/10G.