Loop Spectrum Compatibility and Management

by

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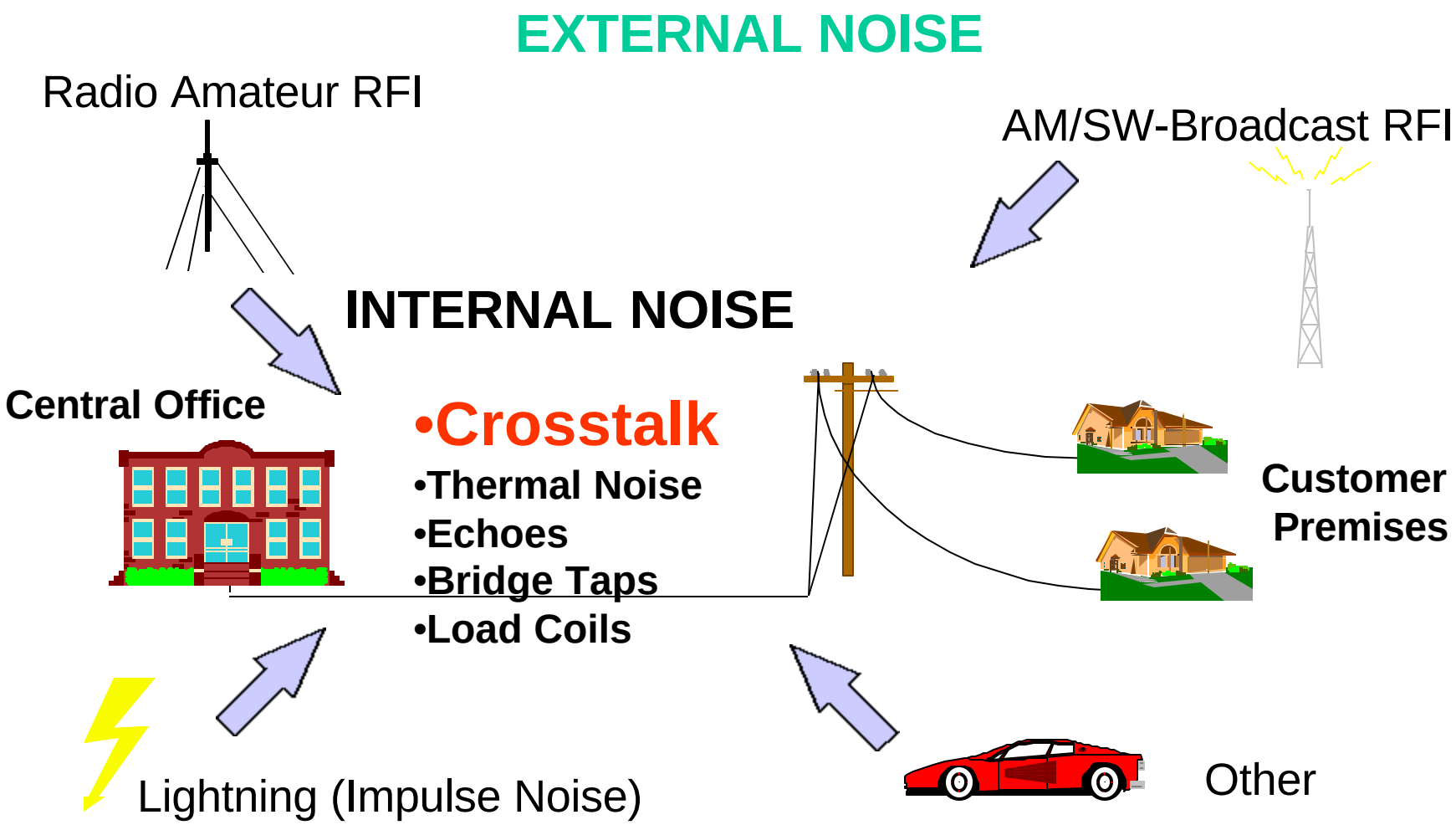
Spectrum Management Mission statement:

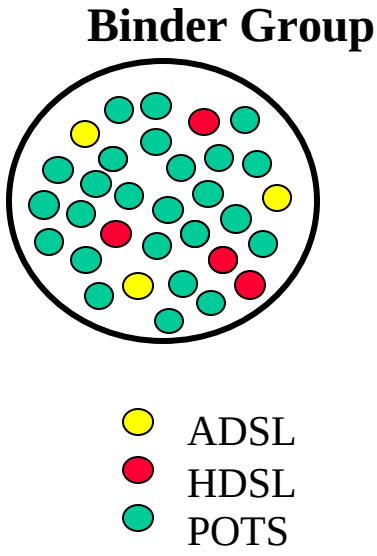
- Utilize installed base of twisted copper pairs for delivering high speed broadband access to the maximum number of customers.
- Manage an unbundled loop environment with many service providers using various xDSL technologies.
- Provide deployment rules to insure that new generations of DSL and legacy technologies do not interfere with each other.

Local Loop Environment



U.S. Loop Plant Information

- Typical Cabling
  - Binder Groups have 10, 25, **50** or 100 pairs
  - Up to 50 Binder Groups per Cable
- Loop Plant Design
  - Resistance Design for Voice Services
    - Loading coils at greater than 15-18Kft
    - Max 1500 Ohms, Typical 500 Ohms
  - CSA Design for DDS Services
    - 9Kft-26AWG or 12Kft-24AWG
- Goal of Spectrum Management
  - Do not require nor prohibit binder group segregation by type of transmission system



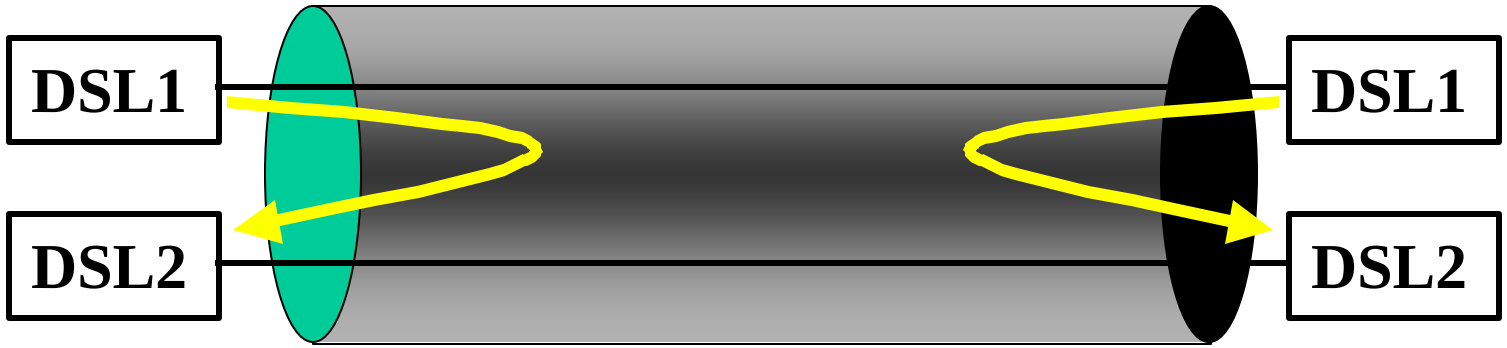
Spectrum Management primarily addresses crosstalk

- Crosstalk: The undesired transfer of a portion of a transmitted signal on one pair of wires onto the other wire-pairs in the same cable via electromagnetic coupling.

- The transferred signal acts as noise injected into the DSL receivers on the other wires. Depending on loop-length and other factors, DSL receivers can tolerate noise and crosstalk below a certain threshold.

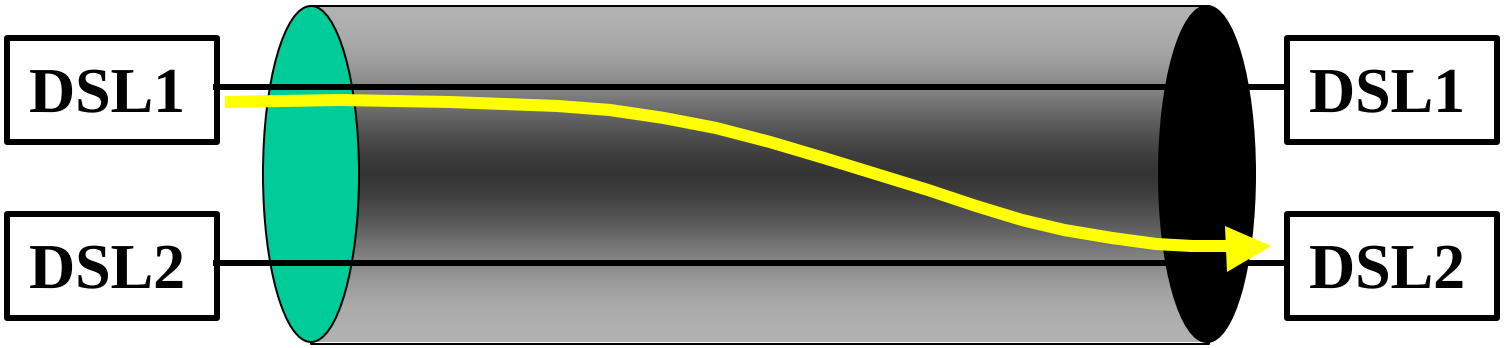
Near End Crosstalk: NEXT

- DSL receiver is effected by coupled noise from transmitter(s) at the same end of the cable. Most important for DSLs using the same frequency bands for transmission in both directions.



Far End Crosstalk: FEXT

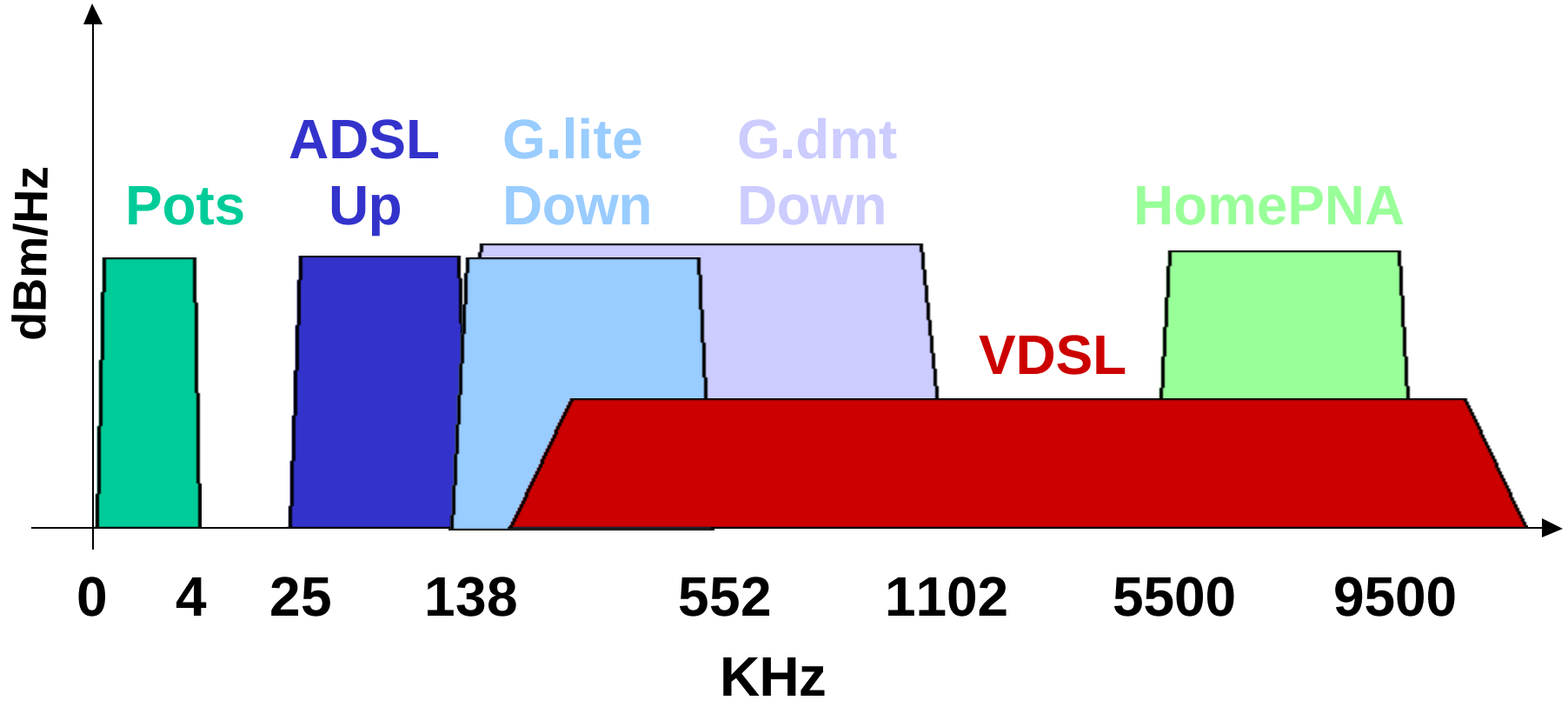
- Receiver is effected by coupled noise from transmitter(s) at other end of the line. FEXT is most important for DSLs using separate frequency bands for each direction of transmission. ADSL is FEXT limited.



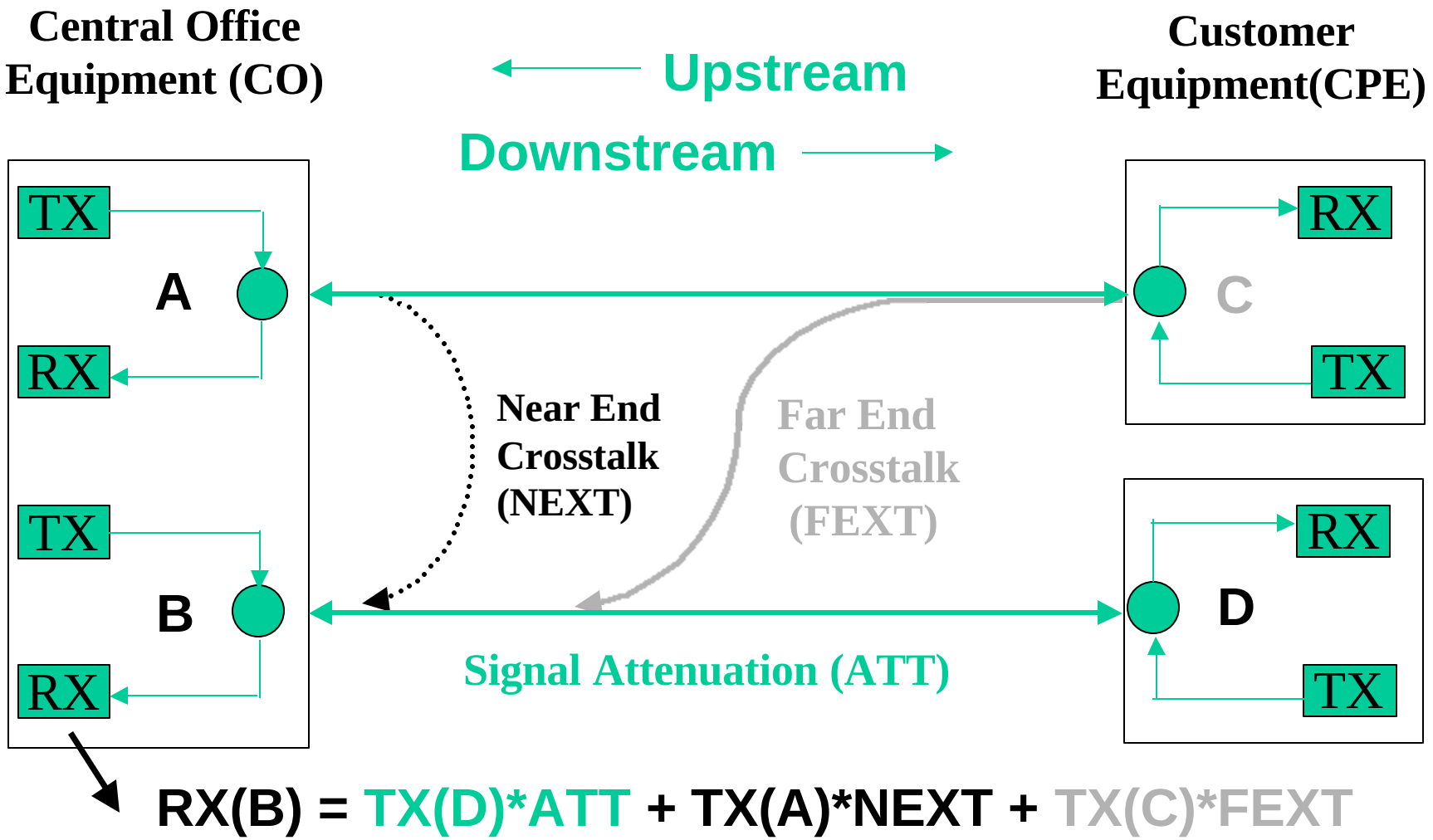
Crosstalk characteristics

- Near-end crosstalk coupling increases with frequency (f 3/2), more critical for higher bit rate systems
- Crosstalk increases with the number of disturbers, the first few disturbers make more of a difference
- Crosstalk increases with the amplitude of the “disturbing” system
- Crosstalk depends on frequency overlap of DSLs upstream and downstream

ADSL/VDSL Spectral Use Example



Combined Crosstalk Configuration



RX(B) = TX(D)*ATT + TX(A)*NEXT + TX(C)*FEXT

Are Spectrum Management rules necessary?

- In our competitive industry there is strong market pressure for equipment vendors and service providers to provide yet higher bit-rate services to more customers.

- The easiest way to do this is to transmit yet more powerful signals that cause increased crosstalk into other systems.

Regulatory developments

- Loop unbundling: Incumbent carriers must permit competing carriers to use local loops. Without guidelines, crosstalk from one carrier's DSL may effect the service provided by a different carrier.
- Spectrum Management: The FCC has requested T1E1.4 to develop Spectrum Management standards, and this is expected to serve as a technical foundation for a forthcoming FCC proposed rulemaking for unbundled loops.
- NRIC-V: The FCC has asked the Network Reliability and Interoperability Council (NRIC-V) to advise on Spectrum Management issues.

Technical standards developments

- For at least 15 years, DSL standard developments have addressed the spectral compatibility of DSL systems through noise performance models.

- T1 Spectrum Management Standard Approved (T1.417) in Nov-2000. Provides generic technical specifications for DSL systems that may safely coexist in the same cable. Now in ANSI review.

- Draft Available (http://www.t1.org/dir2000/0e140026.pdf).

Objectives of T1E1.4 Spectrum Management standard

- Addition of service on other lines should not harm service to existing customers
- Ability to provide service on a line should be accurately predictable
- Once service is provided, it should be reliable for the long term
- Enable innovation and competition of technologies, services, and products
- Practical for use by all vendors and service providers, and enables efficient use of loop plant
- A “living” standard that is updated frequently

Definition of "spectrally compatible"

- A candidate loop transmission system is spectrally compatible with a target system if any number of the candidate systems may coexist in the same cable with the target system operating satisfactorily. A system must be spectrally compatibility with the set of basis systems (**systems that are expected to be used by the largest number of customers in the near term).**

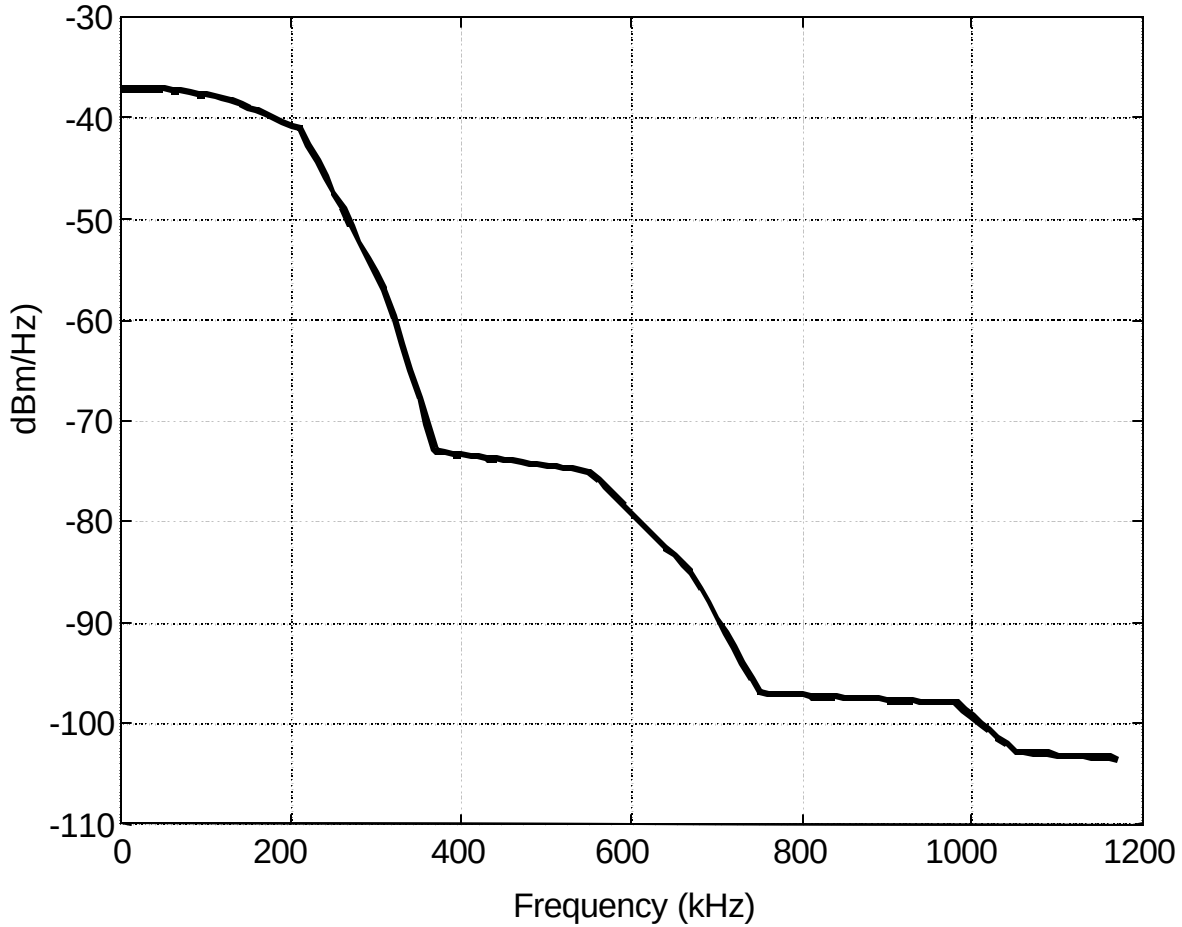
- Signals transmitted in both upstream and downstream directions must meet criteria.

Two methods to show spectral compatibility:

- Method A: Comply with all the criteria defined for any of the defined Spectrum Management Classes. **Spectrum Management Classes (SMC) are supposed to be "technology independent"; in fact they are loosely based on the spectral shape of certain transmission methods.**
- Method B: Meet the criteria of the analytical method defined in Annex A of the draft SM standard. Calculate the effect of a Candidate System on each of the basis systems. Three Technology Specific Guidelines that have been cited are SDSL (2B1Q), and G.shdsl (G.991.2 Symmetric) and HDSL4 (G.991.2 Asymmetric)

SMC3 PSD Template

Signal must be below the PSD mask which is 3.5 dB greater than the PSD template (shown here).



Spectrum Management Class list from T1. 417standard:

Class	Example System	Deployment Guidelines(EWL)
1	DDS (<115 kHz)	all nonloaded loops
2	ISDN (<238 kHz)	11.5 kft
3	HDSL (<370 kHz)	9 kft
4	HDSL2 (<300 kHz)	10.5 kft
5	ADSL (<138/1100 kHz Up/Dn)	all nonloaded loops
6	VDSL (<20 MHz)	under study
7	SDSL (<776 kHz)	6.5 kft
8	SDSL (<584 kHz)	7.5 kft
9	ADSL (Overlapped Spectrum)	13.5 kft

- **Loop lengths are Equivalent Working Length (EWL) 26 AWG.**

Complex issues on ADSL

- As a frequency division multiplexed system, ADSL is not effected by self-NEXT.
- Thus, ADSL is performance is primarily limited by NEXT from other types of DSL.
- To what degree is ADSL performance compromised verses restrictions on loop-reach of other types of DSL?
- There is a trade-off between the performance of the respective types of DSL.

Open Issues in Current T1.417 Standard

- Mid-Span Repeaters
  - Signal repeated in DLC or RT
  - Crosstalk effects under evaluation
- VDSL
  - Three Trial Standards in Development
  - Currently in T1 Ballot Process
- Non-Stationary Noise
  - Some specifications, but not yet understood

Summary

- "In summary, realization of the megabit capacity of the existing copper access network is critically dependent on understanding and controlling the crosstalk environment to ensure spectral compatibility of new and legacy transmission systems."
  - Cook, Kirby, Foster, Booth, Clarke (all at BT Laboratories), IEEE Communications Magazine, May 1999.

Additional Information

- ITU Standards:
  - www.itu.int
  - Q4/SG15 Reflector: tsg15q4@itu.ch (ITU Members)
- T1E1 Standards:
  - www.t1.org
  - T1E1.4 Reflector: t1e14@t1.org
- DSL Forum:
  - www.dslforum.org
- For More Information:
  - Jim Carlo (jcarlo@ti.com)