COMMUNICATIONS ALLIANCE LTD

INDUSTRY GUIDELINE

G671:2023

G.FAST DEPLOYMENT ON CUSTOMER CABLING

G671:2023 G.fast Deployment on Customer Cabling Industry Guideline

Released for public comment as G671:2023
First published as G671:2023

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INTRODUCTORY STATEMENT

The **G.fast Deployment on Customer Cabling** Guideline (G671:2023) is intended to provide:

- A framework for managed sharing of customer cabling infrastructure within a premises or campus, while ensuring that all end users receive adequate G.fast data rates; and

- A technical basis for determination of whether sharing is viable in cases where G.fast Systems from one Distribution Point Unit (DPU) share customer cabling infrastructure with G.fast Systems originating from another DPU.

Peter Cooke
Chair
G.fast Working Committee

DECEMBER 2023

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1 GENERAL

1.1 Introduction

1.1.1 The development of the Guideline has been facilitated by Communications Alliance through a Working Committee comprised of representatives from the telecommunications industry and Government regulatory agencies.

1.1.2 The Guideline should be read in the context of other relevant codes, guidelines and documents.

1.1.3 The Guideline should be read in conjunction with related legislation and regulation, including:

(a) the *Telecommunications Act 1997* (the Act);

(b) the *Competition and Consumer Act 2010 (Cth)*; and

(c) *Telecommunications Cabling Provider Rules 2014.*

1.1.4 If there is a conflict between the requirements of the Guideline and any requirements imposed on a Carrier or Carriage Service Provider (CSP) by statute, the Carrier or CSP will not be in breach of the Guideline by complying with the requirements of the statute.

1.1.5 Compliance with this Guideline does not guarantee compliance with any legislation. The Guideline is not a substitute for legal advice.

1.1.6 Statements in boxed text are a guide to interpretation only.

1.2 Scope

1.2.1 The Guideline applies to the Carriers and CSP sections of the telecommunications industry under section 110 of the Act.

1.2.2 The Guideline deals with the following telecommunications activities as defined in section 109 of the Act:

(a) carrying on business as a Carrier; or

(b) carrying on business activities as a Carriage Service Provider; or

(c) supplying Goods or Service(s) for use in connection with the supply of a Listed Carriage Service.

1.3   Objectives / Purpose

1.3.1   The objectives of the Guideline are to provide the technical basis for:

(a)   procedures between Carriers and CSPs;

(b)   non-discriminatory arrangements; and

(c)   competitively neutral processes.

1.3.2   The Guideline is intended to provide a framework for managed sharing of customer cabling infrastructure within a premises or campus, while ensuring that all end users receive adequate G.fast data rates.

1.3.3   The Guideline provides a technical basis for determination of whether sharing is viable in cases where G.fast Systems from one Distribution Point Unit (DPU) share customer cabling infrastructure with G.fast Systems originating from another DPU.

1.3.4   Although not mandatory, adherence to this Guideline should ensure that G.fast Systems are not installed or operated in situations that would cause unacceptable interference to other Notified G.fast Systems.

1.3.5   A secondary goal of this Guideline is to provide viable solutions for the evolution from:

(a)   a single DPU, single Provider building System to

(b)   a multiple DPU building with one or more Providers.

> *NOTES:*
>
> *1. This is an area not covered adequately by theC658:2019 rules.*
>
> *2. C658:2019 includes mandatory requirements on G.fast Non-Deployment Class Systems including requirements for:*
> *(a) G.fast Notification that ensure priority over later deployments Notifications; and*
> *(b) spectral shaping of G.fast Systems to prevent interference to Notified VDSL2 Systems, irrespective of which System was first Notified.*

1.4   Guideline review

The Guideline will be reviewed after 5 years or earlier in the event of significant developments that affect the Guideline or a chapter within the Guideline.

2 ACRONYMS, DEFINITIONS AND INTERPRETATIONS

2.1 Acronyms

For the purposes of the Guideline:

3CXT

means Third Circuit Crosstalk.

CCF

means Cross Connect Facility

CE

Means Customer Equipment

CSP

means Carriage Service Provider.

DPU

means Distribution Point Unit.

DS

means Downstream.

FEXT

means Far End Crosstalk.

G.fast

means the System defined by ITU-T Recommendation G.9701.

IDF

means Intermediate Distribution Frame.

MDF

means Main Distribution Frame.

NEXT

means Near End Crosstalk.

TDD

means Time Division Duplex.

US

means Upstream.

VDSL2

means Very high speed Digital Subscriber Line 2.

2.2   Definitions

For the purposes of the Guideline:

Act

means the *Telecommunications Act 1997 (Cth)*.

Carriage Service Provider

has the meaning given by section 87 of the Act.

Carrier

has the meaning given by section 7 of the Act.

Cross Connect Facility

has the meaning given by C658:2019.

Customer Equipment

means modem equipment used by the end user to access a Carrier service.

Deployment Class System

has the meaning given by C658:2019.

Distribution Point Unit

means G.fast equipment that transmits from the network end towards Customer Equipment and is used or installed to deliver a Carrier service.

Downstream

means the direction towards the CE from the DPU.

DPU Serving Area

means the set of end user premises and associated building cabling that the Provider has Notified as being served by a specific DPU.

Full Coverage

means the Provider's DPUs in a building can provide Full Port Coverage and Full Rate Coverage.

Full Port Coverage

means the Provider is able to provide new G.fast services on reasonable request.

Full Rate Coverage

means the Provider is able to achieve at least the net Layer 2 data rate described in Clause 4.3.5 with acceptable stability to all potential end users.

Non-Deployment Class System

has the meaning given by C658:2019.

Notified (including Notification)

has the meaning given by C658:2019.

Provider

means a Carriage Service Provider or Carrier that operates or plans to operate a System in Customer Cabling.

Serving Area

means the set of end user premises and associated building cabling that is served by a Provider's equipment (e.g. DSLAM, DPU, FTTP OLT) at a specified location.

Shared Cable Bundle

has the meaning given by C658:2019 and, for the purposes of G.fast includes any shared Cross Connect Facility such as a Main Distribution Frame (MDF) or Intermediate Distribution Frame (IDF).

System

means a DPU and one or more items of Customer Equipment that is used to access Carrier services.

Third Circuit Crosstalk

means two-step crosstalk from a first wire pair to a second wire pair via one or more nearby wire pairs.

Upstream

means the direction towards the DPU from the CE.

2.3   Interpretations

In the Guideline, unless the contrary appears:

(a)   headings are for convenience only and do not affect interpretation;

(b)   a reference to a statute, ordinance, code or other law includes regulations and other instruments under it and consolidations, amendments, re-enactments or replacements of any of them;

(c)   words in the singular includes the plural and vice versa;

(d)   words importing persons include a body whether corporate, politic or otherwise;

(e)   where a word or phrase is defined, its other grammatical forms have a corresponding meaning;

(f)   mentioning anything after include, includes or including does not limit what else might be included;

(g)   words and expressions which are not defined have the meanings given to them in the Act; and

(h)   a reference to a person includes a reference to the person's executors, administrators, successors, agents, assignees and 7ovates.

3 BACKGROUND AND SUMMARY

3.1 Background

3.1.1 This Guideline has emerged from a long history of regulation that ensures compatible infrastructure sharing of twisted-pair copper cables to reflect government policy, originally for access cables as the ***Unconditioned Local Loop Service (ULLS) Network Deployment*** Industry Code (C559), and later for distribution and building cabling as the ***Next-Generation Broadband Systems Deployment in Customer Cabling*** Industry Code (C658:2019).

3.1.2 Whereas C658:2019 only provides protection from interference for Systems up to VDSL2 frequencies (i.e. less than 20 MHz), it does anticipate and provide some interim rules for the Notification and deployment of G.fast Systems to 212 MHz.

3.1.3 The high crosstalk levels at G.fast frequencies and the inability to synchronise two Time-Division-Duplex (TDD) G.fast DPUs effectively prevent any sharing by those G.fast DPUs of a Shared Cable Bundle.

3.1.4 The C658:2019 rules allowed G.fast to be Notified and deployed as a Non-Deployment Class System, allowing only one G.fast Notification in any Shared Cable Bundle.

3.1.5 C658:2019 Part 1 clause 7.2.17 and Part 2 Appendix E include some informative requirements for G.fast deployment.

3.1.6 The failure to include G.fast as a Deployment Class System in C658:2019 means a Notified G.fast System could still be degraded by interference from a non-Notified G.fast System sharing a Shared Cable Bundle.

3.1.7 When Communication Alliance Working Committee 93 (WC93) attempted to accommodate G.fast as a Deployment Class System under the C658:2019 processes, it found that such changes to C658:2019 could not be completed and implemented in a timely manner for the following reasons:

(a) C658:2019 relies on the concept of Full Coverage which requires a calculation of attenuation that reflects the expected Upstream (US) and Downstream (DS) rates for the longest end user in the DPU Serving Area. Under C658:2019 rules, failure to provide adequate ports for new services or exceeding the required attenuation for any end user can result in another Provider assuming a higher priority and displacing the incumbent. In C658:2019 this assumed relationship between attenuation and rates is only valid for Cat 3 and Cat 5 or Cat 6 cables with known relationships between the attenuation and the crosstalk levels that determine rates.

(b) Attenuation and crosstalk characteristics at G.fast frequencies for many building cables are unknown and

would require extensive measurement, often *in situ*. Even if all cables were measured, the different combinations of attenuations and crosstalk levels at the higher frequencies used for G.fast and the need to compute rates for cascaded cable types would require much more complex calculations of attenuation benchmarks for Full Rate Coverage.

(c) G.fast is subject to higher crosstalk levels and more complex Third Circuit Crosstalk (3CXT) degradations, both of which are made worse by cable unbalance that may result from faults such as bad joints or connectors, making any guarantee of performance problematic.

(d) The impact of crosstalk from an alien G.fast System originating from another DPU would need calculations on a per-symbol basis with multiple noise profiles due to the noise sampling process and unsynchronised TDD implementation of G.fast.

3.1.8 Consequently, WC93 has developed this Guideline to inform the industry and regulators of the technical measures and approaches that are required to maintain adequate G.fast performance in twisted pair building cables.

3.2 Summary

3.2.1 This Guideline covers the technical effects and impacts on end user experience and does not address commercial or competitive outcomes, except to identify situations where such issues may require resolution.

3.2.2 Destructive interference between G.fast Systems is avoided by ensuring that Systems originating from different G.fast DPUs have adequately separated cable routes. That is achieved by not sharing a Shared Cable Bundle at any point on the routes between DPUs and end users.

3.2.3 Evolution from a single DPU to multiple DPUs in a building or campus is based on the concept in C658:2019 of Full Coverage.

3.2.4 When a single DPU is unable to provide Full Coverage of its DPU Serving Area, either due to inadequate port count or inadequate service rates to the most distant end users, methods for subdivision of the DPU Serving Area into smaller mutually exclusive DPU Serving Areas are recommended.

3.2.5 The Guideline also recommends methods for recognition of interference between G.fast Systems. That interference may result from inadvertent sharing of a Shared Cable Bundle, or from 3CXT via other circuits such as legacy copper or VDSL2 Systems that overlap both DPU's Shared Cable Bundles. Methods for resolution of such identified causes are also recommended.

3.2.6   Although the Guideline is not enforceable as an industry code, the bidirectional nature of interference, that will degrade both G.fast Systems, provides incentive for Providers to heed the proposals in the Guideline.

4 C658:2019 IMPLICATIONS FOR G.FAST

4.1 G.fast in C658:2019

4.1.1 C658:2019 was originally written for VDSL2 deployment, with G.fast references added at a later date. While the concepts of "Full Coverage" and "Shared Cable Bundle" are defined in C658:2019, some further clarification is provided here for G.fast.

4.1.2 Full Coverage is based on a Full Port Coverage requirement to be able to serve a new end user and a Full Rate Coverage requirement to be able to provide the required target rates up and down to all end users in the DPU Serving Areas. Government bit rate policy at the time C658:2019 was drafted was for a minimum universal broadband rate of 25 Mbps. However because G.fast is capable of substantially greater rates than 25 Mbps, and G.fast cannot operate reliably at a rate as low as 25 Mbps, a higher minimum threshold is necessary for G.fast technology. G.fast can operate up to maximum aggregate rate of about 1.5 Gbps on Australian cables on shorter cable runs.

4.1.3 A Shared Cable Bundle is defined in C658:2019 as:

"Shared Cable Bundle means any grouping of pairs of conductors where the proximity of the cable sheaths and/or pairs of conductors in the grouping have the potential to cause Unacceptable Interference between them.

NOTES:

1. This includes groupings of separate cables that run together for some or all of their routes.

2. However a properly earthed screened cable does not become part of such larger Shared Cable Bundle but remains as its own separate Shared Cable Bundle.".

4.1.4 For the purposes of G.fast interference, DPUs that share a Cross Connect Facility (CCF) (e.g. MDF or IDF) are considered to have shared a Shared Cable Bundle. That means a second DPU should not be jumpered through any CCF used by the first DPU. End users' lines served by the second DPU that were connected to blocks on the customer side of the CCF used by the first DPU must be re-connected to a second CCF (which may be integrated with the second DPU) and remain well separated from that first CCF and DPU.

4.1.5 Note that a G.fast DPU Serving Area consists of a multiplicity of Shared Cable Bundles. At any point in a cable carrying G.fast, the local instance of the Shared Cable Bundle can be viewed as a cross-section encompassing all cables in the near vicinity.

4.1.6 For a DPU not to share a Shared Cable Bundle with another G.fast DPU, it should not be possible for a DPU to share any instance of a

Shared Cable Bundle with another DPU. The avoidance of such sharing should be achieved by either:

(a) Ensuring that potential DPU Serving Areas of the DPUs (i.e. all pairs that could be jumpered to the separate DPUs) never overlap a common instance of a Shared Cable Bundle; OR

(b) Implementing pair allocation rules for the DPUs to prevent sharing of a Shared Cable Bundle. For example, a DPU on floor 1 may serve floors 1 and 2, and a second DPU on floor 3 may serve floors 3 and 4. However the requirement to be able to jumper legacy services to all floors means that the DPU on floor 1 could also be jumpered to a G.fast service to floor 4 and cause interference in Shared Cable Bundles. Such cases should be prohibited by pair allocation rules.

4.1.7 For the purposes of this Guideline, the presence of a Shared Cable Bundle, evidenced by the potential to cause unacceptable interference between G.fast Systems from different DPUs occurs whenever their Cat 3, Cat 5 and Cat 5e cables are within 10cm or so for any distance exceeding about 10 cm. For Cat 6 cabling or above the extent to which this can be relaxed is for future study (FFS).

4.2 Existing Mandatory Requirements for G.fast Deployment from C658:2019

4.2.1 C658:2019 mandates protection of all Notified VDSL2 Systems by filtering out the VDSL2 frequency range from the G.fast signal.

4.2.2 Despite C658:2019 prohibiting the Notification of a second G.fast Non-Deployment Class System in a Shared Cable Bundle, there is no guaranteed protection from interference from a non-Notified System under C658:2019, which only provides protection for Deployment Class Systems. The risk of interference is very high with G.fast technology which is highly vulnerable.

4.2.3 Whereas C658:2019 uses mandatory requirements to prevent unacceptable interference into systems confined to below 20 MHz, this Guideline for frequencies above 20 MHz uses the same concepts of Full Coverage, Notification and resolution of interference in a non-mandatory manner.

4.3 G.fast Full-coverage Performance Expectations

4.3.1 Target bit rates are a matter of policy and can be varied by the Government of the day, but targets for G.fast have not been provided at this stage.

4.3.2 The working committee that wrote C658:2019 endeavoured to reflect policy preference for infrastructure and spectrum sharing using a concept of Full Coverage, and the same approach is adopted here.

4.3.3   G.fast suffers from a range of interference and cable degradations, including crosstalk from adjacent pairs, indirect crosstalk via third circuits, impulse noise bursts from external sources, cable joint issues and cable pair unbalances that exacerbate external interference. Together these causes and the complexity of G.fast mechanisms result in adaptive best effort rate outcomes that cannot be accurately predicted, and instability (i.e. dropouts and error bursts) that is managed through several processes including rate reduction.

4.3.4   Based on diverse opinions of its members, the committee considers that for adequate stability of a G.fast System in a fast changing interference environment, the minimum viable Layer 2 data rates should lie in the ranges 200 to 250 Mbit/s DS and 25 to 50 Mbit/s US, with VDSL2 spectral masking active.

NOTES:

1. Actual download and upload rates may be significantly lower than the Layer 2 data rates at times due to congestion in networks and other degradations beyond the G.fast system.

2. Layer 2 data rates may be time varying due to retransmission of errored frames and changing interference environments. The use of average Layer 2 data rate over an interval of the order of 5 to 15 minutes is recommended.

3. Some G.fast Systems suffer instability (excessive dropouts) resulting from a range of fault conditions.

4. Some G.fast Systems can be degraded to below the Layer 2 target rates by fault conditions in the cables including high resistance or open terminations, external interference exacerbated by cable unbalance, etc.

5. If the System is unstable the Provider should investigate and correct the problem either by finding and repairing a fault or interference source or by adjusting System parameters.

6. If the System suffers consistent or frequent Layer 2 data rate excursions below the minimum target rate up or down, the Provider should investigate for an interference, cable unbalance, or other intermittent fault cause and rectify. Failure to rectify in a reasonable time should void any claim of Full Coverage.

7. Although clause 4.3.4 refers to minimum Layer 2 data rates DS and US, the designer has the option to vary the duty cycle of the time division multiplexing. Hence the maximum design range for Full Rate Coverage depends only on the target minimum net Layer 2 data rate.

4.3.5   Full Rate Coverage for G.fast Systems, with the VDSL2 band masked out as required by C658:2019, requires all Systems off the DPU to have net Layer 2 data rates greater than a minimum in the range 225 to 300 Mbit/s.

4.3.6   It is recommended that, instead of performance calculations based on cable data as used in C658:2019, the Full Rate Coverage performance measure be based on direct measurement of the rates of the slowest stable Systems. A Notified Provider should only claim Full Coverage of the building or campus, or subdivision thereof, if both Full Rate Coverage and Full Port Coverage can be achieved across its DPUs in the building.

4.3.7   A Provider that cannot provide Full Coverage with a single DPU, either because of inadequate port counts or inadequate data rates, can subdivide the domain as in Section 5.4 to retain Full Coverage. Without Full Coverage, an incumbent Provider should not be able to prevent other G.fast deployment in the building or campus, provided that deployment is based on a technically sound subdivision of the building as described in Section 5.4.

5   G.FAST IN MULTIPLE PROVIDER DEPLOYMENTS

5.1   Introduction

5.1.1   G.fast intrinsically relies on effective vectoring in order to provide reliable service. When two or more independent G.fast DPU Systems share a Shared Cable Bundle, crosstalk interference from an alien G.fast System can render vectoring ineffective, resulting in degraded rate and stability, and in some cases outright failure.

5.1.2   For that reason, it is recommended that the Serving Areas of multiple G.fast DPUs in a building should always be constrained to consist of mutually exclusive instances of Shared Cable Bundles.

5.1.3   Even when two DPUs occupy mutually exclusive DPU Serving Areas, other continuous cable pairs not used by G.fast Systems may overlap Shared Cable Bundles used by separate DPUs, providing a 3CXT path between those Shared Cable Bundles.

5.1.4   The analysis of 3CXT is complex and not easy to include in a simplified Guideline. Section 5.3 addresses some common 3CXT scenarios and provides suggested remedies to block that crosstalk when problematic.

5.1.5   Multiple G.fast deployments in bundled 4-pair Cat 5 or Cat 6 cable may not suffer from significant crosstalk degradation due to the greater pair separation and tighter twisting of the pairs.

5.2   Suggested Approach to Sharing of Cables and Shared Cable Bundles

5.2.1   While the primary requirement to prevent unacceptable interference has been stated above, approaches that enable competition between G.fast Systems within a building should be addressed.

5.2.2   The C658:2019 use of Full Coverage can form a basis for such an approach, but with the direct measurement of the rates of the slowest System from a DPU as described in Section 4.3.5.

5.2.3   A Provider wishing to overcome port unavailability or to improve data rate performance for end users may subdivide the building into multiple DPU Serving Areas, each with Shared Cable Bundles that should be mutually exclusive from Shared Cable Bundles in all other DPU Serving Areas.

5.2.4   End users not receiving the desired Full Coverage rate should be excised from their DPU Serving Area and restored to Full Rate Coverage in the excised serving area(s). Failure to maintain Full Port Coverage should also be rectified by subdivision of the DPU Serving Area. The incumbent G.fast Provider or a second Provider should serve a suitable excised area or areas with one or more new DPUs or alternative solutions. The Notification under C658:2019 for the original DPU should be changed to reflect the reduced serving area. Additional DPUs serving excised DPU

Serving Areas should be Notified as Non-Deployment Class Systems under C658:2019.

5.2.5　The suitability of an excised Serving Area for a new DPU or other solution should be based on the following considerations:

(a)　A new DPU should be able to serve all end users in its excised DPU Serving Area over mutually exclusive Shared Cable Bundles, relying on new IDF provision as required.

(b)　The first Notified DPU's residual DPU Serving Area that remains after the planned excisions of Serving Areas should have Full Rate Coverage and should serve the anticipated demand for the foreseeable future.

(c)　The new DPU or alternative solution (such as fibre to the end user) should be capable of Full Rate Coverage of the excised area and should serve the anticipated demand in that excised area for the foreseeable future.

(d)　Examples of viable solutions are provided in Section 5.4.

5.2.6　Following Notification of an excised DPU Serving Area as in clause 5.2.4, the incumbent Provider should either:

(a)　Propose and implement its own Full Coverage solution for that excised Serving Area, at which time any second Provider's Notification lapses; or

(b)　Upon first G.fast deployment from the additional DPU by itself or the second Provider, disable at the original DPU and transfer to the additional DPU all G.fast services feeding from the original DPU into the excised DPU Serving Area.

5.2.7　Provided Full Coverage is retained for that new DPU, the first Notification of an excised DPU Serving Area should preclude further deployment by another Provider of G.fast in that DPU Serving Area.

5.2.8　In such situations, it may also be necessary to avoid or mitigate 3CXT between those mutually exclusive DPU Serving Areas as described below.

5.3　Potential for 3CXT degradation and possible remedies

5.3.1　Sharing arrangements where a basement Provider feeds multiple floors of a building and a second G.fast Provider serves one floor, or the top n floors, can lead to two step 3CXT via legacy and VDSL2 connections that feed up the riser onto the floors served by the second Provider as shown in Figures 2 and 3. The lack of cable crosstalk data and the need to address each specific arrangement make it difficult to estimate the impact of 3CXT on both DPU's Systems. Because severe interference is unlikely, it is suggested that such deployments be implemented and monitored. When 3CXT degradation is present, the installation of

a low pass filter and longitudinal choke in the IDF jumper on each offending third circuit would minimise degradation (see Figure 1).

5.3.2   Three step 3CXT may occur between G.fast DPUs using different segments of a riser cable, where there are overlapping connections through riser Shared Cable Bundles. Such 3CXT paths are unlikely to cause problems.
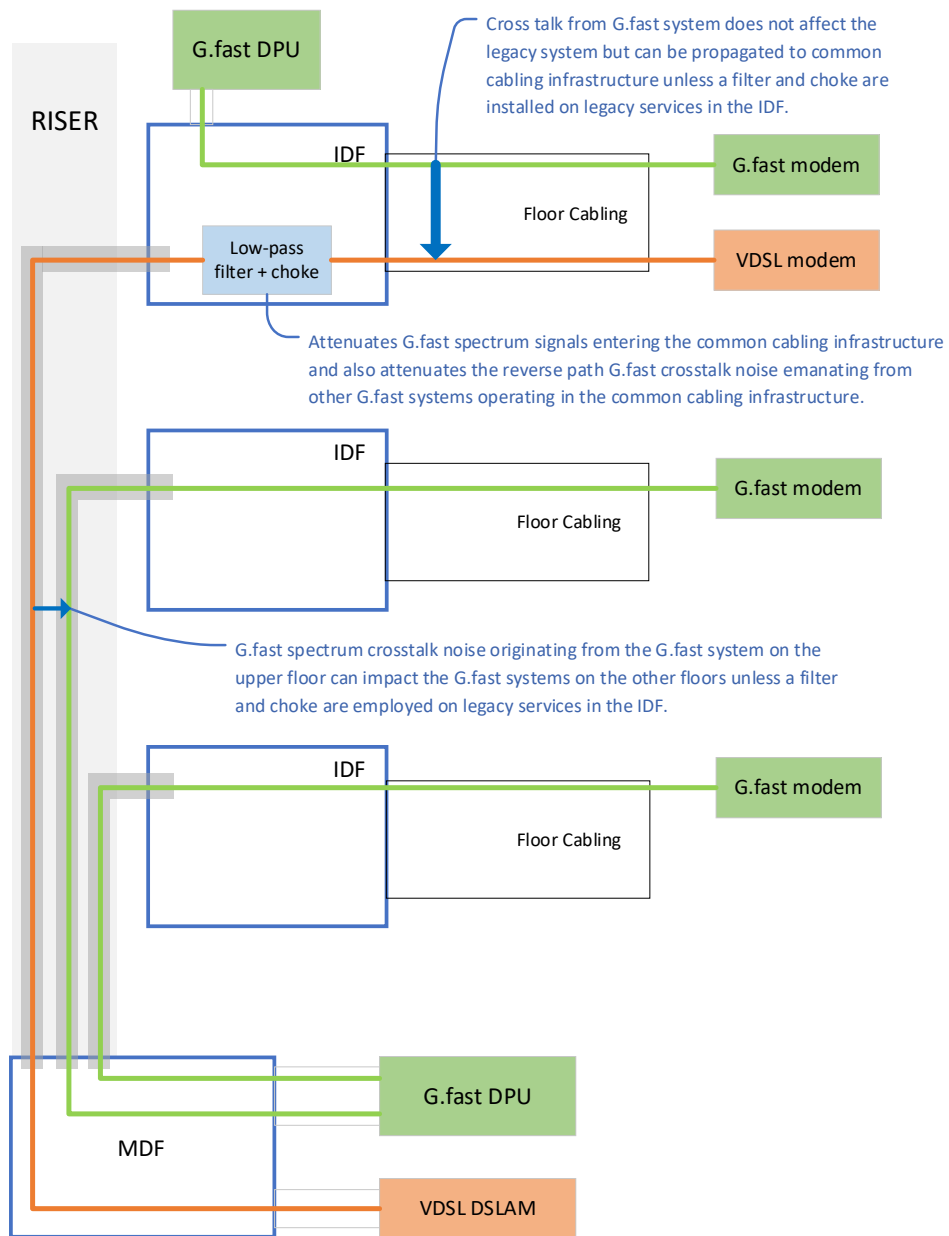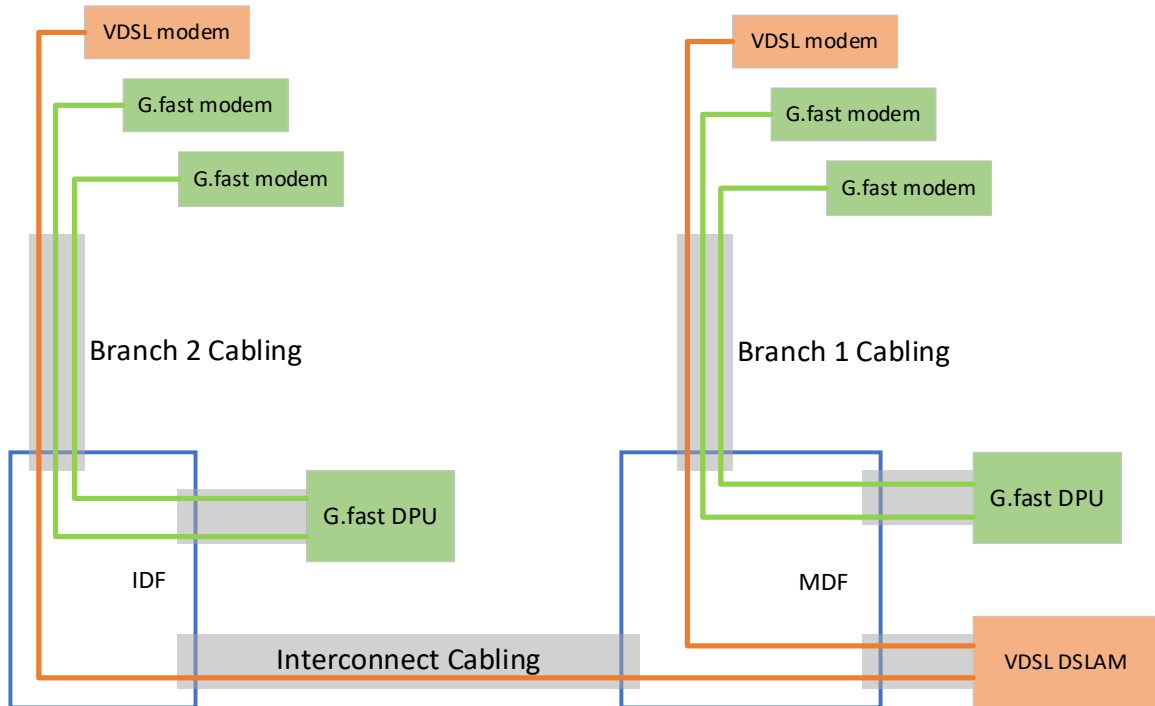
FIGURE 1

**Third Circuit Crosstalk paths between G.fast Systems
via overlapping copper paths**

NOTES:

1. Blue arrows represent G.fast signals coupling via a VDSL2 third circuit to a foreign G.fast domain.

2. The reverse path also interferes.

3. Longitudinal modes on the third circuit are blocked by a choke.

4. Differential modes on the third circuit are blocked by low pass filter that admits VDSL2 frequencies but attenuates higher G.fast frequencies.

## 5.4 Mechanisms for subdividing a building into multiple G.fast DPU Serving Areas.

5.4.1 The ability to subdivide a building or campus into mutually exclusive G.fast DPU serving areas is strongly dependent on the cabling layout. If there are mutually exclusive Shared Cable Bundle runs radiating from a central location, then each could potentially support a different G.fast DPU. Further subdivision of one such Shared Cable Bundle run, for example of a riser cable in a multi-story building, is only possible by the insertion of intermediate feed-in locations for DPUs, for example at an IDF feeding one floor level where no other G.fast may be feed into that floor level.

5.4.2 In all cases separate DPU Serving Areas should not share any common Shared Cable Bundles.

5.4.3 The scenarios listed below, while topologically the same, require different network modifications in order to implement a second G.fast DPU:

(a) Central branching (see Figure 2). From the MDF, multiple DPUs may each feed a mutually exclusive group of Shared Cable Bundles .

(b) Multiple remote branches (see Figure 3). A DPU may serve multiple branches (e.g. floors 4 to 6) provided feeds from a DPU lower on the tree are prohibited from feeding G.fast spectrum through that DPU Serving Area, including any riser cable that DPU may use to serve multiple floors.

FIGURE 2

**Two DPUs at an MDF location feeding
different branches of building/campus cabling**

5.4.4   In Figure 2, the following apply:

(a)   Systems from separate DPUs should never share a CCF. The first DPU may only be connected through the MDF to one such branch or group of branches and should not be connected through the IDF. The second DPU may only be connected through a subsidiary IDF to a second mutually exclusive branch or set of branches. That second set of branch cables should no longer appear on the MDF after they have been re-connected to an added IDF.

(b)   Network services to the second branch should be jumpered through the main MDF to a customer-side block that is hardwired to a block on network side of the IDF for that branch. Only active services should be jumpered through the MDF and IDF, with unused jumpers removed to avoid 3CXT.

(c)   If 3CXT is problematic, the use of a low pass filter and choke is recommended to be used in each IDF jumper for a network service.

(d)   Note that the IDF Cross Connect Facility may be provisioned as part of the DPU but must allow legacy VDSL2 and copper services to be through connected.
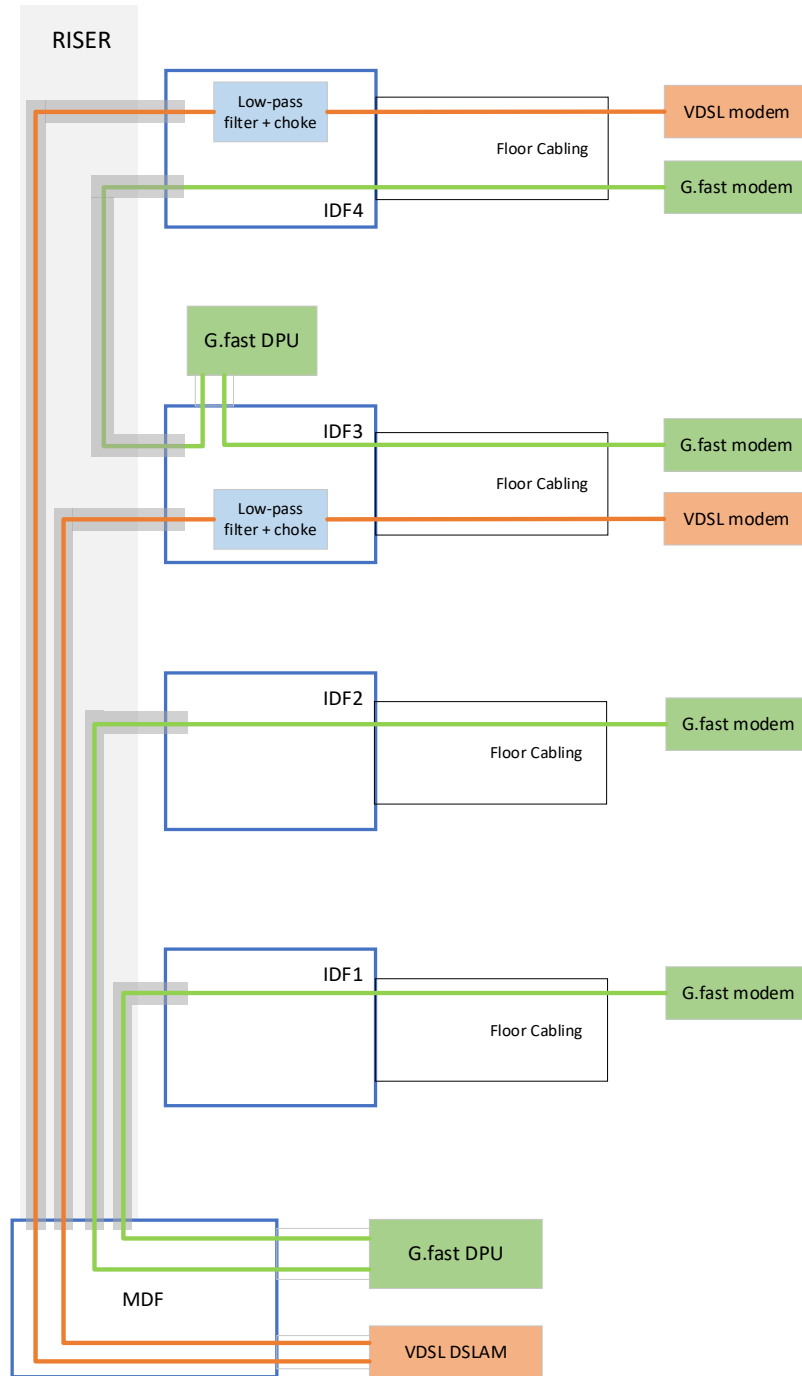
FIGURE 3
Each DPU serves multiple floors of a building

5.4.5   In Figure 3, the following apply:

(a)   the easiest way to connect the second DPU to higher floors is by adding new interconnect cables in the riser. In some cases that would require extra blocks on the higher floor IDFs. Riser cabling from the MDF should be left in place for delivery of network or building based non-G.fast services.

(b)   G.fast Systems from the first DPU should not be connected through any of the IDFs served by the second DPU.

(c)   Only active services should be jumpered through the IDFs, with unused jumpers removed to avoid 3CXT. If 3CXT is problematic, the use of a low pass filter and choke is recommended to be used in each IDF jumper for a legacy service.

6 INTERFERENCE CASES THAT REQUIRE CORRECTION

6.1 Introduction

6.1.1 Interference between G.fast Systems from different DPUs that share a Shared Cable Bundle is observed to periodically vary between more severe Near End Crosstalk (NEXT) and less severe Far End Crosstalk (FEXT) as the clocks of the Systems slip with a period of several minutes.

6.1.2 With more than two Systems, there may be overlapping cycles of different periods. The resulting cyclic data rates of both Systems are a clear indication of a potential sharing of the Shared Cable Bundle or possibly of 3CXT. A technical explanation follows.

6.2 Alien G.fast crosstalk impact

6.2.1 If a second DPU's G.fast System is present and there is some significant alien crosstalk coupling between the two Systems (either direct or via 3rd circuit) then cyclical variation of bitrates may be seen on both G.fast Systems as a result. Where there is significant alien crosstalk there may be also other impacts on performance e.g. errored or severely errored seconds (ES, SES) which may also exhibit cyclic behaviour. In severe cases some lines may lose synchronisation or may not be able to achieve synchronisation.

6.2.2 Cyclic variation of bitrate can be used as an indicator of alien crosstalk. Where cyclic rate reduction is seen on one G.fast System it is likely that the other G.fast System will be impacted also.

6.2.3 The cyclical variation is due to drifting G.fast frame alignment between the two Systems due to differences in the G.fast clock frequencies (which are normally determined by crystal oscillators that always have a finite accuracy/tolerance). The rate of frame alignment drift is typically such as to cause the bitrates to cyclically vary with a period of the order of 5 minutes or less.

6.2.4 The G.fast Time Division Duplexing (TDD) frame structure contains US and DS symbol periods. When the second (alien) G.fast System TDD frame is not time aligned with the first System TDD frame then near-end and far-end alien crosstalk will occur at different instants of the frames. Alien NEXT occurs when the two Systems are transmitting in opposite directions at a particular time instant and is more severe (stronger) than alien FEXT. It is known that even short coupling distances can lead to significant NEXT.

6.2.5 It may be noted also that G.fast vectoring can only cancel FEXT from lines of the same G.fast DPU; i.e. not from an alien System. NEXT for lines of the same DPU is avoided using TDD.

6.2.6 By monitoring G.fast line rates e.g. during the commissioning phase for a period of approximately 30 minutes it is possible to detect the impact of alien crosstalk if present. Cyclic noise

margin variations may also be seen even if the impact is not sufficient to trigger a rate change via Seamless Rate Adaption (SRA) or Fast Rate Adaption (FRA) mechanisms. If the US and/or DS rate is seen to vary in a cyclic way over the 30 minutes then that is an indication of alien crosstalk impact and the depth of variation is an indication of severity.

6.2.7   The cyclic variation of US/DS bitrates will normally have a somewhat rectangular "wave" shape (if plotted) with a typical period of the order of 5 minutes. The "duty cycle" of the rectangular wave will be determined to a large extent by the TDD ratio in use (i.e. the relative number of DS and US symbol periods).

6.3   Resolution of Conflicting Deployments

Where the introduction of a new System, that uses the G.fast frequency bands above 2 MHz and below 212 MHz, causes interference to an existing System, the following approaches are recommended.

(a)   Interference from a G.fast System to a C658 Notified VDSL2 System must be minimised by shaping the G.fast transmit spectrum as required by C658:2019.

(b)   Whenever there is interference between Systems, all Providers should check that their Systems are well balanced, as faulty circuits with poor balance are much more susceptible to and more likely to cause interference.

(c)   Because the first Notified G.fast Non-Deployment Class System that retains Full Coverage should be protected from interference, it is important to check for sharing of Shared Cable Bundles. A second non-Notified or incorrectly Notified System should be removed from any Shared Cable Bundle occupied by the first Notified G.fast DPU.

(d)   Where there is interference between non-overlapping G.fast Systems that do not share a Shared Cable Bundle at any point, one or both Providers should investigate for the presence of third circuits that overlap both DPUs' Shared Cable Bundles. Interference should be reduced by breaking connections on unused third circuits where possible, or by blocking the G.fast signals on in-use third circuits with a longitudinal choke and a low pass filter that admits VDSL2.

(e)   Interference to and from other Systems that use the G.fast spectrum including Ethernet over unshielded twisted pair Systems including 100BaseTX, 1000BaseT, 2.5GBaseT, 5GBaseT, and 10GBaseT on Cat 5e, Cat 6 etc might interfere with G.fast if sharing the same cable sheath, but are unlikely to interfere within the same Shared Cable Bundle.

7 REFERENCES

Publication	Title
Industry Codes	
C559:2010	Unconditioned Local Loop Service (ULLS) Network Deployment
	https://commsalliance.com.au/Documents/all/codes/c559
C658:2019	Next-Generation Broadband Systems Deployment in Customer Cabling
	https://commsalliance.com.au/Documents/all/codes/c658
Broadband Forum publications	
BBF TR-285	Broadband Copper Cable Models Issue: 2 Amendment 1
	https://www.broadband-forum.org/technical/download/TR-285_Issue-2_Amendment-1.pdf
Legislation and Regulation	

Telecommunications Act 1997

https://www.legislation.gov.au/Series/C2004A05145

APPENDIX

A   Technical Data on Cables and Crosstalk levels

A1   Broadband Forum (BBF) contribution from nbn

A.1.1   **nbn** made a contribution to the PhyTX group within the Broadband Forum for amending TR-285i2 - Broadband Copper Cable Models to include Australian cable models.

A.1.2   The list of cables within the contribution was not completely published in *TR-285 – Broadband Copper Cable Models Issue 2, Amendment 1* as some cables have already had extensive study and are already well-known.

A.1.3   For completeness in this text, please find below the equations used and parameters determined for each cable type from the study (see Table 1).

A.1.4   Cable attenuation where f is frequency in Megahertz, *Attenuation(1MHz)* is the measured attenuation of 100m of cable at 1 Megahertz and K' is a co-efficient representing attenuation losses due to crosstalk

$$Attenuation\ (f) = Attenuation(1MHz)\sqrt{f} + K'f^2$$

A.1.5   FEXTR is the far-end crosstalk ratio where f is frequency in Megahertz, FEXTR(1MHz) is the measured FEXTR over 100m of cable at 1 MHz, and *p* represents a suspected second order crosstalk path that occurs at higher frequencies

$$FEXTR\ (f) = Max\{0, FEXTR(1MHz) - 20 * \log_{10}(f) - pf\}$$

A.1.6   NEXTA is the near-end crosstalk attenuation normalised to 100m where f is in Megahertz, NEXTA(1MHz, 100m) is the measured NEXTA of 100m of cable, $Slope_N$ is the normal slope for the cable arrangement, f_t is the transition frequency between $Slope_N$ and $Slope_2$, and $Slope_2$ is the second slope at higher frequencies

$$NEXTA\ (f, 100m)$$
$$= NEXTA(1MHz, 100m)$$
$$- Slope_N \log_{10}(f) \left\{ \text{if}(f > f_T) then\ Slope_2 * \log_{10}\left(\frac{f}{f_T}\right) else\ 0 \right\}$$

A.1.7   FEXTPSR is the far-end crosstalk power sum ratio of M disturbers where f is in Megahertz, FEXTPSR(1MHz, M=4) is the FEXTPSR measured at 1 MHz with 4 disturbers, and the remainder of the equation shares the same variables as FEXTR

$$FEXTPSR\ (f, M) = FEXTPSR(1MHz, M = 4) - 6 * \log_{10}\left(\frac{M}{4}\right) - 20 * \log_{10}(f) - pf$$

A.1.8   NEXTPSA is the near-end crosstalk power sum attenuation of M disturbers where f is in Megahertz, NEXTPSA(1MHz, M = 4) is the NEXTPSA measured at 1 MHz with 4 disturbers, the remainder of the equation shares the same variables as NEXTPSA

$NEXTPSA\ (f, M)$

$$= \text{NEXTPSA}(1\text{MHz}, \text{M} = 4) - 6 * \log_{10}\left(\frac{M}{4}\right) - \text{Slope}_N * \log_{10}(f)$$

$$- \left\{\text{if}(f > f_T) then\ Slope_2 * \log_{10}\left(\frac{f}{f_T}\right) else\ 0\right\}$$

TABLE 1
Cable Characteristics

Cable type	Pair Comb	Atten 1MHz	K'	FEXTR 1 MHz	FEXTPSR 1 MHz,4d	p	NEXTA 1MHz	NEXTPSA 1MHz,4d	SlopeN	f$_T$	Slope2
CPFUT .4 10pr WU	45	1.9	.00085	63	46.6	.053	56	40.5	15	N/A	0
CPFUT .4 10pr WP	100	1.9	.00085	92	75.4	.21	91	75.5	15	7	10
PEIFLI .4 quad WP	6	1.9	.00007	79	61.6	.01	77	57.6	15	N/A	0
HT57 2pr WP bw-bw	28	1.8	.000009	85	69.5	0	93	77.4	10	N/A	0
HT57 2pr WP rb-rb	28	1.56	.00001	79.5	55.3	.015	83	67.5	10	N/A	0
HT57 2pr WP rb-bw	28	1.68 mean	NA	108	92.4	0	114	98.5	15	N/A	0
Cat3 Riser 25pr WU	45	1.9	.00012	70	50.9	.016	68	49.6	15	100	10
Cat 5e WP	6	2.1	.000005	94	74.3	0	98	82.3	15	N/A	0
Cat 6 WP	6	2.0	0	98	78.3	0	103	85.3	15	N/A	0

NOTES: 1. CPFUT means 'Cellular Polyethylene Filled Unit Twin'; PEIFLI means 'Polyethylene Insulated Filled Lead In'.

2. 'WU' means 'within unit' (i.e. within the same unit (or binder) of a cable);

'WP' means 'within pipe' (i.e. between separate cables within the same cable bundle)

3. 'bw' means 'blue white', 'rb' means 'red black'.

A2   3CXT measurement results or 3CXT model fits

A.2.1   3CXT measurement results

The measurement results below, intended to represent the case of Figure 1, were taken from a 100-pair CAT3 cable with a 3CXT measurement between two simulated adjacent floors separated by about 5 m of cable. Extended tails in the measurement represent the cabling on the upper floor and the riser cable passing the lower floors. The tests were for the case where each cable unit or binder group is terminated on only one floor, so that third circuits are only in adjacent cable units and never within-unit. Notably the 3CXT follows a 25 dB per decade line of best fit which is similar to other reported measurements. It is understood that the dominant mode of 3CXT in this scenario is multiple double-NEXT paths which should result in about 30 dB/decade slope. The slightly lower observed slope is likely due to correlation effects when summing over the many longitudinal or common mode third circuit paths in adjacent cable binders.
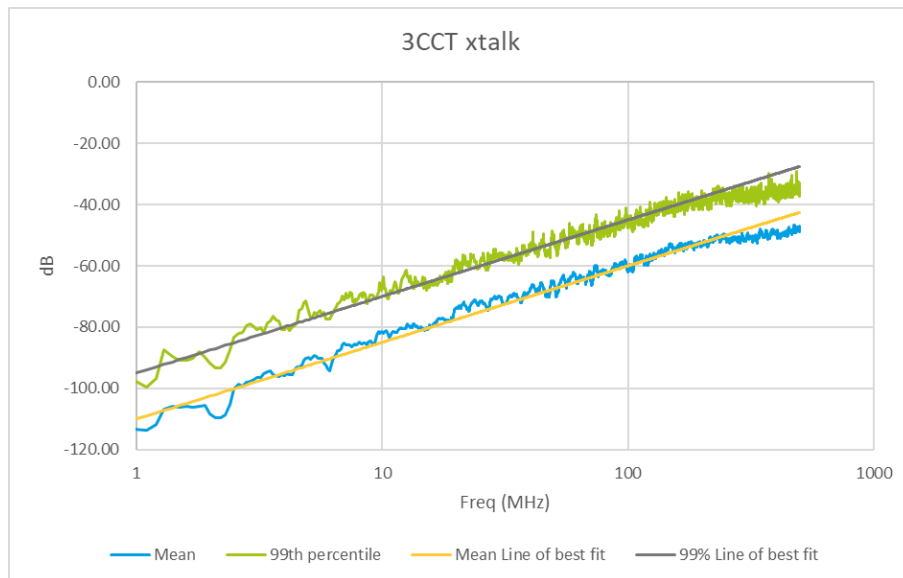
FIGURE 4

3CXT between simulated floors using 100-pair CAT3 cable
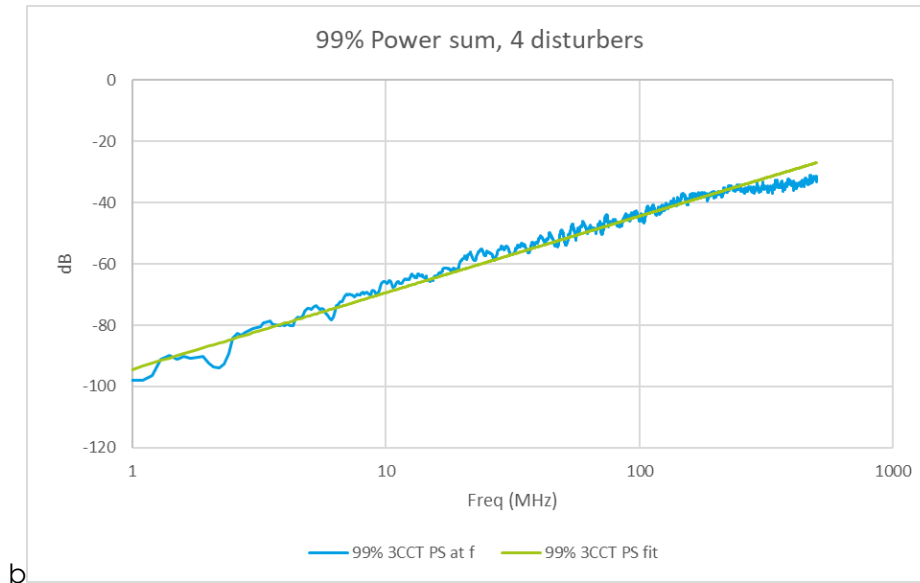
FIGURE 5
99th percentile 3CXT power sum with 4 disturbers

A.2.2   3CXT model fits

Note that the 3CXT slope is higher than FEXTR slope so that 3CXT becomes more significant at the higher G.fast frequencies. At 100 MHz on Cat3 riser cable, which has higher twist and lower crosstalk than access cables, the power sum 3CXT is about -44 dB, while the residual power sum FEXT is -9.3 dB minus the vectoring gain which is less than 20 dB. In that case 3CXT remains insignificant compared with residual FEXT. In cables with stronger crosstalk, or under fault conditions where unbalance results in much higher NEXT to the longitudinal or common mode, the 3CXT could be comparable to the FEXT.

PARTICIPANTS

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Australian Communications and Media Authority	Non-voting	Dominic Byrne
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Communications Alliance was formed in 1997 to provide a unified voice for the Australian communications industry and to lead it into the next generation of converging networks, technologies and services.

In pursuing its goals, Communications Alliance offers a forum for the industry to make coherent and constructive contributions to policy development and debate.

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