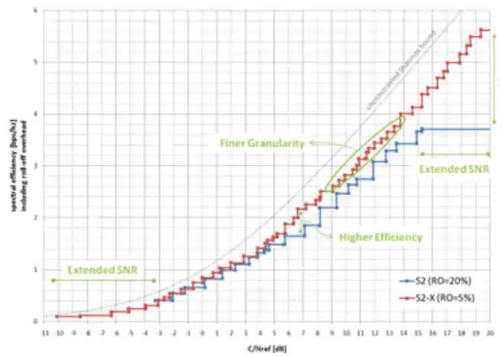
DVB-S2 to S2X

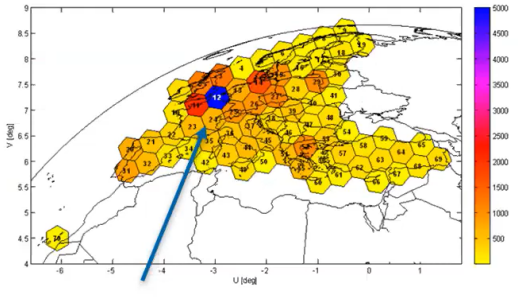
- DVB-S2: March 2005, EN302307
- DVB-S2X : October 2014, EN… part 2
- Main improvements were
  - More MODCODs -> Higher dynamic range (VLSNR, 256APSK), smaller gaps between MODCODs
  - Time slicing (new header) -> manageable complexity
  - Lower roll off -> more efficient BW use
  - Scrambling -> Tighter beams (spot beams)
  - Channel bonding -> statistical mux



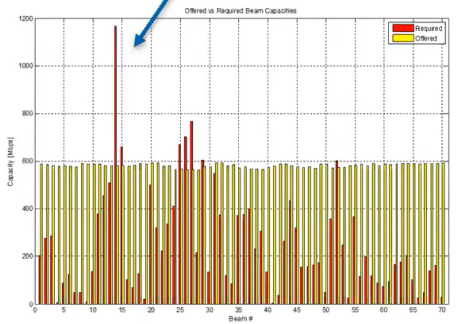
簡報重點項目	**對應 ETSI EN 302 307-2 V1.1.1 章節**
更多 MODCODs（如 VLSNR、256APSK）	§5.4（特別是 §5.4.7）、§5.5.2.5、§5.5.2.6
Time slicing（新 header）	附錄 M（Annex M）
Lower roll-off（更低滾降因子）	§5.1.6（RO 支援 0.05、0.10、0.15）
Scrambling（導向更窄波束）	§5.5.4（特別是 §5.5.4.1）
Channel bonding（通道綁定）	§5.1.8、§5.1.8.1～§5.1.8.3
右下角圖表：性能提升（Finer Granularity、Extended SNR、Higher Efficiency）	§5.4、§5.5、§5.4.0、§5.5.2.5、§E.3.6

New requirements

- The S2X standard was all very well but:
  - The standard did not easily allow for dynamic reallocation of resources.
  - Satellite capacity tended to be fixed at launch
    - Satellite throughput limited by amplifiers and TWTs
  - Some areas (cells) required much more capacity than others.
  - More flexibility in throughput allocation was required.



Some cells require more capacity



簡報重點項目

DVB-S2X 難以動態資源重新分配

衛星容量於發射時即被固定

各區域需求不均

圖片（容量地圖、需求與供給柱狀圖）

對應 ETSI EN 302 307-2 V1.1.1 章節

本文件未明確支援 Beam Hopping，需透過未來增修（此問題促成 Annex E 之後的制定，後續版本支援 Beam Hopping ）

標準未定義動態容量管理；此屬運用層設計考量，未於 EN 302 307-2 中直接處理

規格書未提供動態時頻重配置機制，此為標準推進的動機背景

非直接摘自 ETSI 標準，應屬簡報作者模擬分析，用以說明「靜態容量配置不符實際需求分布」的問題背景

New Technologies

- Satellite technology moved on.
  - Ferrite switches, regenerative payloads, electronically steerable antennas…
  - Bandwidth could now be allocated to each cell as a function of time.
- -> BEAM-HOPPING
  - Studies showed that 20% improvement in unmet demand[1]
- In order to exploit the potential the DVB-S2 standard had to be upgraded again.

簡報項目	對應 ETSI EN 302 307-2 V1.1.1 章節	說明
Ferrite switches、regenerative payloads、ESA antennas	❌ 未於此規範中描述	規格書專注於 PHY/MAC 層標準，未涵蓋具體硬體技術（此為背景技術陳述）
Bandwidth allocation per cell over time	❌ 無支援動態時域調度	正因無法支援，才促成後續 Beam Hopping 標準（如 Annex E, Format 5–7）制定
Beam Hopping 與 20% unmet demand 改善	⚠️ 非本規格書內資料	此為參考外部研究報告：**ETSI TR 102 376-2 V1.1.1 (2015-11)**，屬於實作指導性技術報告，不在 EN 302 307-2 主文件內
“標準需再次升級”	✔️ 關聯於標準演進背景（Annex E 引入）	Beam Hopping 是 EN 302 307-2 後續版本（含 Annex E）中新增的重要功能

DVB-CM-S and Beam-Hopping

- In October 2017 the CM agreed that CM-S should work on commercial requirements
  - amending the DVB-S2X specification to include optimisations for beam-hopping.
  - chairmanship of Thomas Wrede.
- In October 2018, the DVB-S-CM published a set of commercial requirements for Beam-Hopping (DVB-S CM-S0050).
- The main requirements were:
  - Enable a wider range of applications
    - IOT, flight connectivity, Consumer broadband, maritime, IP trunking..
  - Evolution, not revolution
  - Technical requirements:
    - high illumination ratios (period on vs off), single or multiple carriers per beam, low power, low latency, GEO, MEO, LEO…
  - Interoperability between equipment providers and service providers
  - Holistic approach
    - updating linked standards where appropriate: SI, GSE, RCS

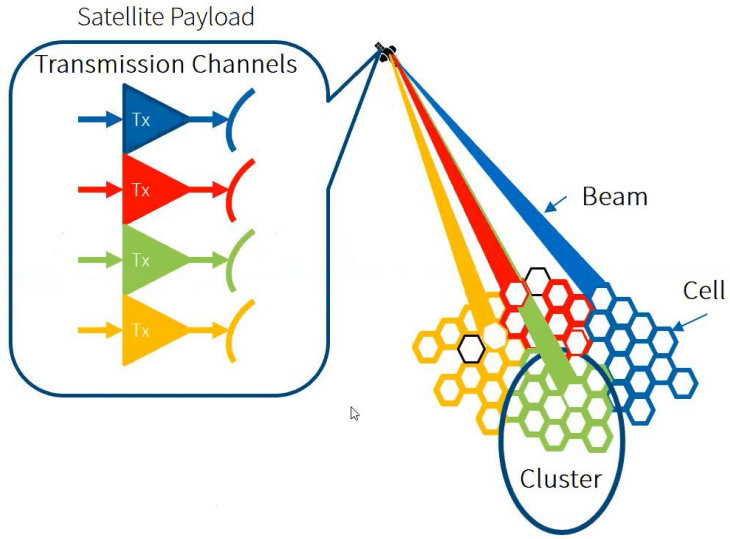
簡報項目	對應來源	備註說明
DVB-S-CM 商業需求制定歷程（2017–2018）	DVB-S CM-S0050	非 ETSI 標準，為商業規格草案文件
商業需求重點（應用廣度、演進導向、技術條件）	DVB CM-S0050 §2–§4	成為制定 Annex E Beam Hopping 技術依據

DVB-TM-S and Beam-Hopping

- In June 2018 DVB-TM-S, under the chairmanship of Alberto Morello, was mandated to work on the new standard
- Over to Nader…

Basic Definitions

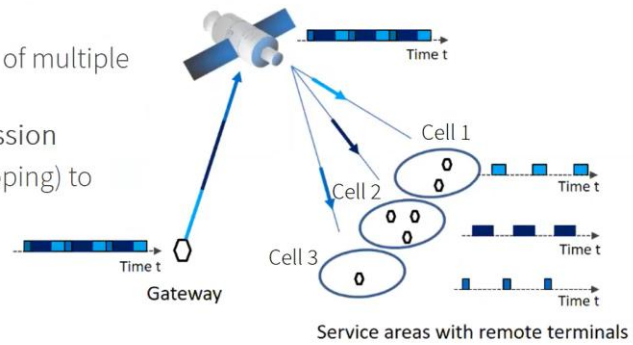
- A Beam is a directional Radio Signal Transmitted from a Satellite Transmission Channel towards a Cell
- At any given time only one Cell within a Cluster is illuminated.
- A Transmission Channel is serving one Cluster
- The Beam Hopping Time Plan determines cell dwell times and the BH Cycle within a cluster.



簡報定義項目	是否來自 **ETSI EN 302 307-2**	對應章節／說明
Beam（波束）為定向無線訊號	✔	定義於 **Annex E, §E.1 概述**，用於描述時間分配單元
Transmission Channel	✔	**Annex E, §E.1–E.2**，傳輸通道對應於衛星 payload 資源
Cell 為基本服務單位	✔	在 **§E.2.2–E.2.3** 中描述，每個 cell 於任一時刻僅一個被啟動
Cluster 組成多個 Cell，且由一個 Transmission Channel 支援	✔	§E.2.3 說明 Cluster 與 Channel 映射關係
Beam Hopping Time Plan 決定 dwell time 與 BH cycle	✔	§E.2.4「Time plan」與 §E.3.6 描述此機制

Beam Hopping Concept

- Satellite Gateway to User Terminal Forward Link:
  - Time-multiplexing data traffic of multiple cells within each Cluster
  - Typically a Wideband Transmission
  - A satellite beam switching (hopping) to different Cells
- Reconfigure according to changing traffic demands and user locations
- Applicable also to the Return Link



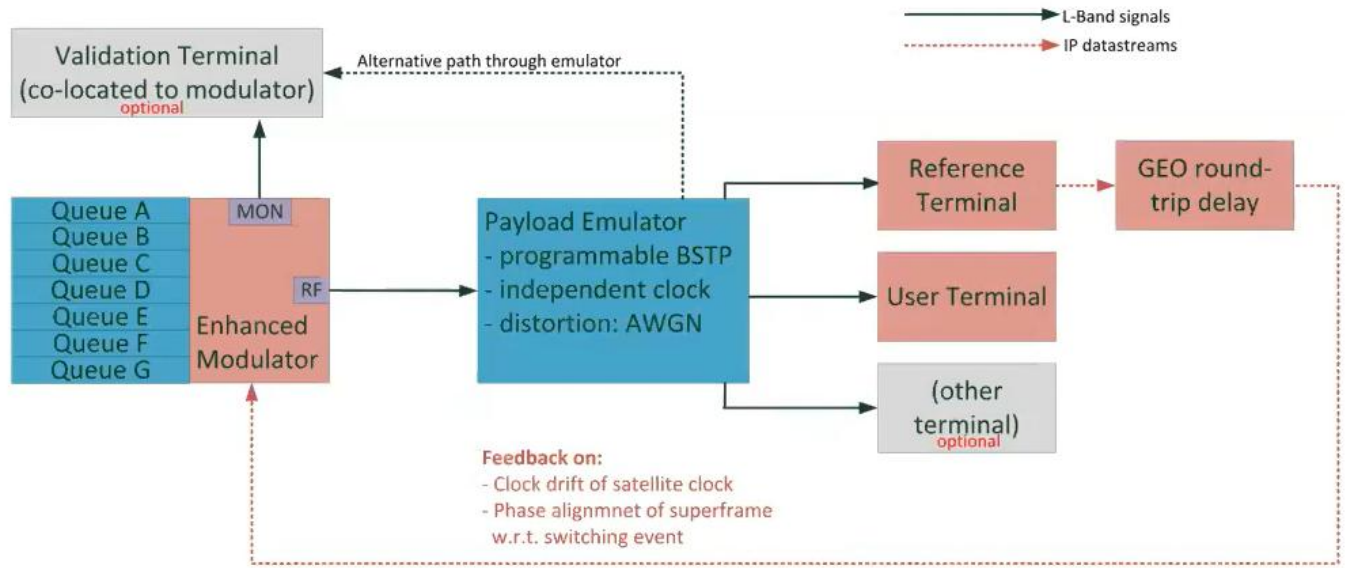
簡報內容項目	是否來自 **ETSI EN 302 307-2**	對應章節／說明
Time-multiplexing 多個 cell 的資料	✔	**Annex E, §E.2.2–E.2.4**：定義 cluster 中單一 cell 時域輪替模式
Wideband Transmission	✔	**§5.1.7**：多種 bandwidth mode 的支援。Annex E 中假定使用寬頻通道（格式 5–7）
Beam 切換（beam hopping）至不同 cell	✔	**§E.2.4, §E.3.6**：描述 beam hopping 時序與 cell switching
根據 traffic demand 調整配置	✔（間接）	§E.2.4 提到 time plan 可根據需求重構，但實際調整策略為實作層考量
回傳鏈路（Return Link）亦可應用	✘（本規格僅涵蓋 Forward Link）	ETSI EN 302 307-2 專注於 forward link；回傳鏈路應由其它標準處理（如 RCS）

R&D Activities

Proof of Concept :

- Beam Hopping Emulator for Satellite Systems:

https://artes.esa.int/projects/behop

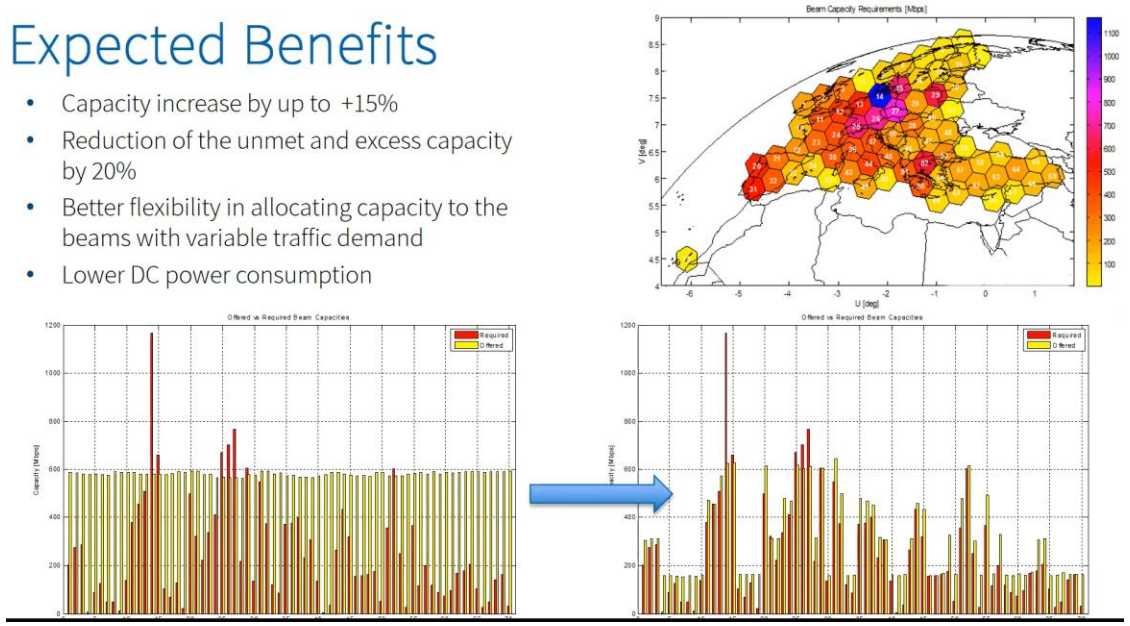


System Studies:

- Beam Hopping Techniques in Multi-Beam Satellite Systems

https://artes.esa.int/projects/beam-hopping-techniques-multi-beam-satellite-systems-eads-astrium

https://artes.esa.int/projects/beam-hopping-techniques-multibeam-satellite-systems-indra-espacio

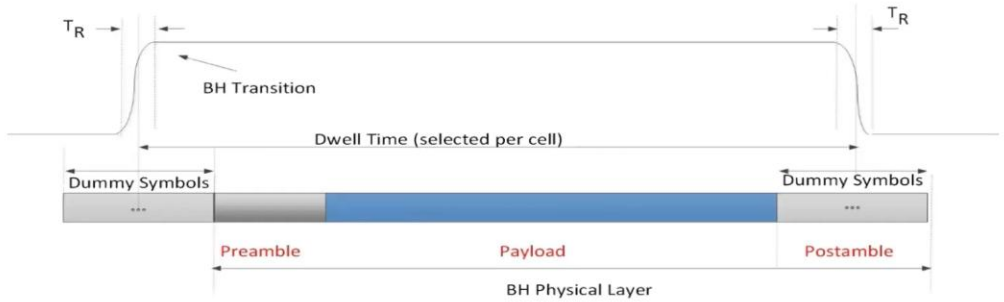


簡報內容項目	是否來自 ETSI EN 302 307-2	說明
容量提升最高達 15%	否	來自 DVB 商業報告（如 DVB-S CM-S0050）與實驗研究，如 ETSI TR 102 376-2
未滿足與多餘容量減少 20%	否	屬於系統模擬結果，未於 ETSI 標準正文中明列，但在技術報告中提及
更靈活的容量配置能力	✔（間接）	Annex E 的格式 5–7 實現動態 beam/cell 時域分配，支持此效益
更低的直流功率消耗	否	實作層面效益，非 ETSI 標準定義內容

Air Interface Technical Overview

A sketch of the Physical Layer Changes:

1. Before each burst, introduce a TRAINING SEQUENCE (Preamble) to allow receiver synchronization:
2. Between bursts, introduce a IDLE-SEQUENCE to allow satellite beam switching: Post-amble

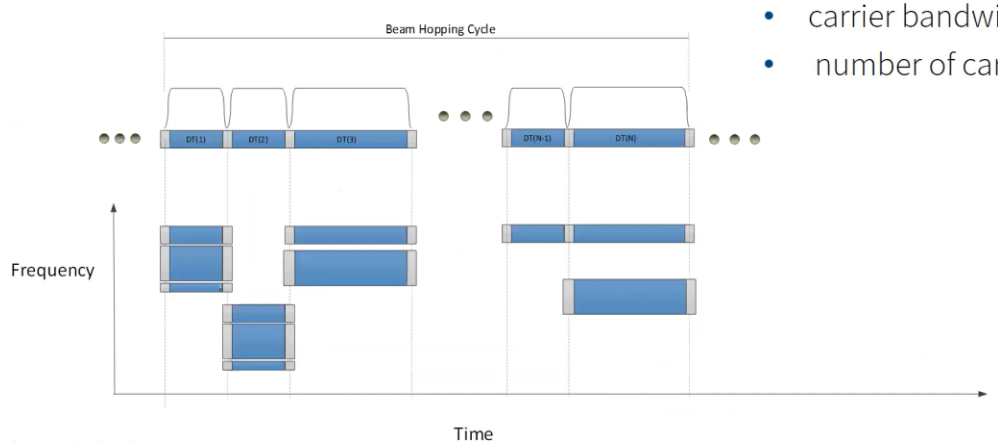


簡報內容項目	是否來自 **ETSI EN 302 307-2**	對應章節
TRAINING SEQUENCE（ Preamble ）	✔	**§E.3.2 – Preamble structure**：每次 burst 開始前插入
IDLE-SEQUENCE（ Postamble ）	✔	**§E.3.4 – Postamble 訊號設計**，確保 Beam 切換與同步
Dummy Symbols 用於空窗區間	✔	**§E.3.1–E.3.4**，說明空檔與 BH transition
BH Dwell Time & Transition	✔	**§E.2.4** 與 **§E.3.5**，具體定義各段時間分佈與參數

A Generic Beam Hopping Model

A beam hopping transmission channel may switch:

- the carrier frequency,
- carrier bandwidth and
- number of carriers (per cell)



簡報內容項目	是否來自 **ETSI EN 302 307-2**	對應章節或說明
Beam Hopping Cycle 時間結構	✔	**§E.2.4, §E.3.5**：定義 cell 時域切換與週期性分配
每一 Dwell Time (DT) 配置載波	✔	**§E.3.6 – Physical Layer Config**，支援每個 cell 有獨立參數
可切換 carrier frequency	✔	**§E.3.6**：每 cell 可指派特定 carrier frequency
可切換 carrier bandwidth	✔	**§E.3.6**：支援不同載波頻寬
不同 cell 可有不同數目 carriers	✔	**§E.3.6** 中 carrier_config 列出多重配置可能性

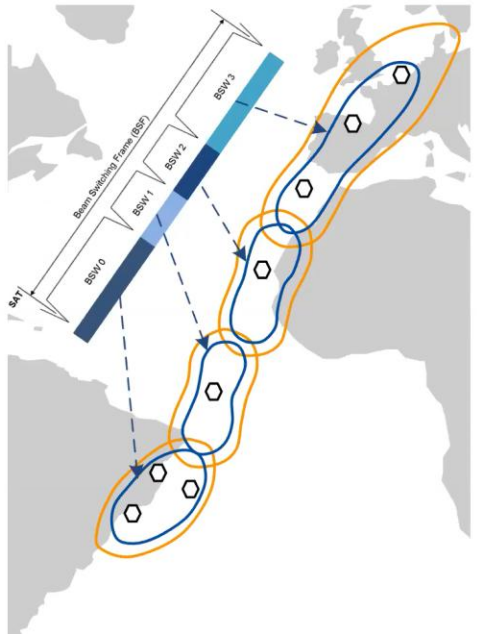
Beam Hopping System Scenarios

Satellite systems:

- Multi-beam GEO satellites (HTS, VHTS)
- Medium Earth Orbit Satellites
- Low Earth Orbit constellations

Potential applications:

- Broadband bi-directional traffic (B2B, B2C)
- Maritime, Airborne In-Flight Communications
- VoIP (low delay and jitter),
- IoT (low power consumption of user terminal)



簡報內容項目	**是否來自 ETSI EN 302 307-2**	**說明**
多波束 GEO/HTS/VHTS 衛星支援 Beam Hopping	✔	ETSI 規格在 §1 與 Annex E 提及多波束靈活性支援
MEO、LEO 系統支援	✘	未明確列於 ETSI EN 302 307-2，屬於產業延伸應用
VoIP、IoT 等低延遲或低功耗應用	✘	無列於 ETSI 技術層規格中，屬於商業應用考量
圖片中的 Beam Switching Frame（BSF）概念	✔（延伸示意）	Beam Switching Time Frame 對應 Annex E 中 Dwell Time & Switching Logic，但圖為視覺化設計

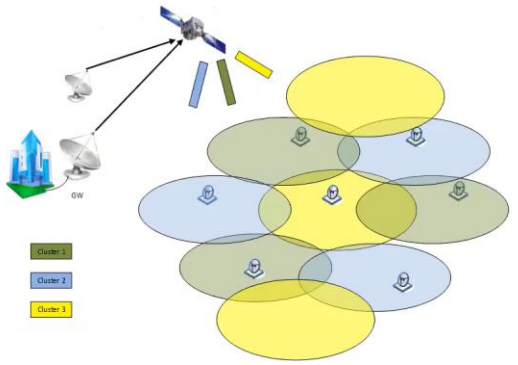
Beam Hopping Operation Strategies

Prescheduled BH cycles:

Regular and periodic illumination pattern

Traffic Driven BH:

Non-periodic illumination pattern (Beam Hopping Time Plan), driven by traffic profile.



簡報內容項目	是否來自 **ETSI EN 302 307-2**	對應章節或備註
Prescheduled BH Cycles	✔	Annex E.2.4: 描述定義週期性 BH Time Plan 結構與範例
Traffic Driven BH（根據流量動態調整）	✔	Annex E.2.4 與 E.3.5 中明確提到 traffic profile 為 beam hopping time 分配的參考依據
圖片內容（GW、Cluster 配色）	❌（視覺化示意）	圖片為非標準原圖，為簡報者自製示意，但概念與 ETSI 描述一致

Traffic Driven Beam Hopping

Point and Shoot

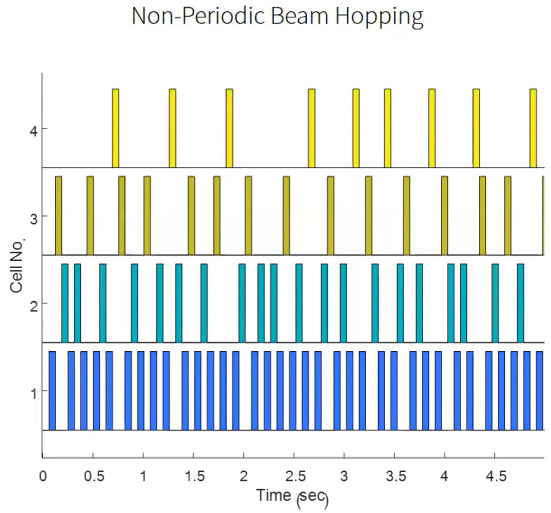
Every packet to a user is directly transmitted

Quality of Service

More Flexibility to minimize Scheduling Delay (higher QoS)

Fixed Container Strategy

Fixed size transmission packet. Transmitted when filled up.



簡報內容項目	是否來自 ETSI EN 302 307-2	對應章節或備註
Point and Shoot每個封包直接傳輸給用戶	✔	附錄 E.3.5 描述 dynamic traffic assignment 與 user-specific scheduling
Quality of Service（高彈性、低排程延遲）	✔	附錄 E.3.5 提及支持 QoS 排程的能力與資源分配控制
Fixed Container Strategy（固定大小的傳輸單元）	✔	附錄 E.3.1 明確定義 transmission frame 可為固定容器設計（container-based scheduling）
Non-Periodic Beam Hopping 圖示	✔（示意圖形）	附錄 E.2.4 與 E.3.5 中討論非週期性 beam hopping 配置（traffic-adaptive BH time plan）

Beam Hopping Channel Model

Performance Evaluation:

- Acquisition Mode
- Tracking Mode

Performance Metrics:

Acquisition Modes

- Mean Acquisition Time
- Estimation Statistics of Sync. Parameters

Tracking Mode

- Frame Error Ratio
- Header Decoding Ratio

Parameters	Acquisition	Tracking
Carrier Frequency Offset	340 kHz	[1 kHz +1kHz]
Carrier Symbol Rates	57.526 MBaud	57.526 MBaud
Symbol Rate Offset	15 ppm	1 ppm – 1 ppm
Timing Offset	Uniformly distributed in [-Ts/4 +Ts/4]	Uniformly distributed in [-Ts/4 +Ts/4]
Initial Phase Offset	Uniformly distributed in [-π +π] interval	Uniformly distributed in [-π +π] interval
SNIR	-9.5 dB	-9.5 dB 0 dB 10 dB

簡報內容項目	是否來自 **ETSI EN 302 307-2**	對應章節或備註
Acquisition Mode / Tracking Mode 定義	✔	附錄 E.5 中定義 performance mode 測試方法
Carrier Frequency Offset = 340 kHz（Acq）	✔	附錄 E.5 表格建議 acquisition 模式測試條件
Symbol Rate Offset（15 ppm / ±1 ppm）	✔	同上：明確列出 acquisition 與 tracking 測試差異
Timing Offset 分布範圍	✔	附錄 E.5 建議使用 uniform distribution
SNIR 測試（−9.5dB、0dB、10dB）	✔	附錄 E.5 建議的典型信號雜訊比測試值
初始相位偏移（Initial Phase Offset）	✔	附錄 E.5 規定 uniform 分布於 [−π, +π]

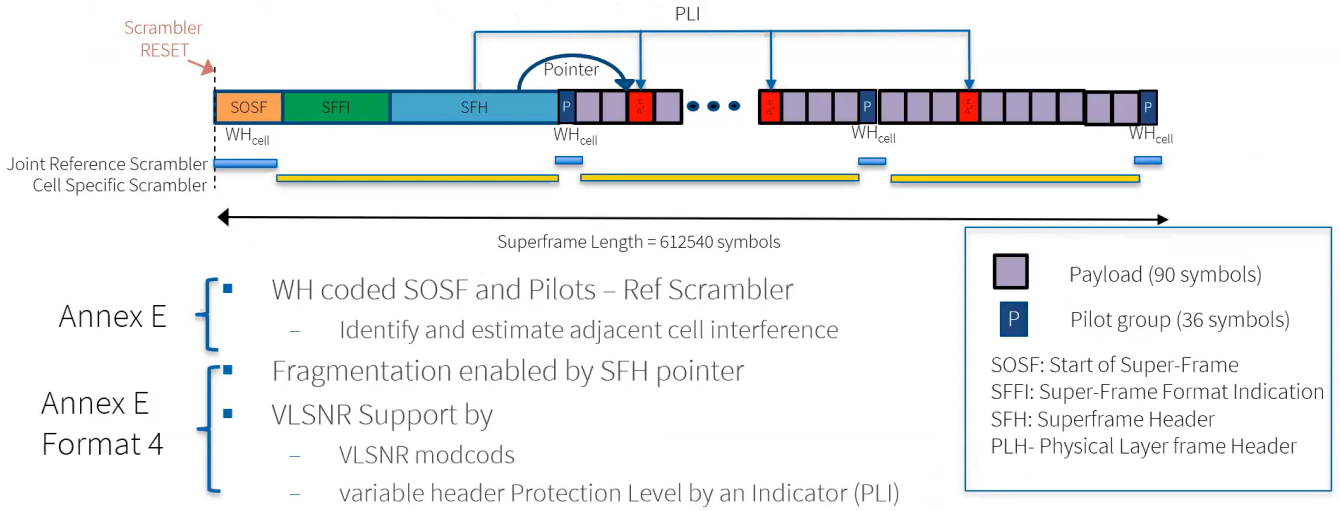
DVB-S2X Waveforms for Beam Hopping Support

- Based on Annex E superframes
  - Supports **multibeam** operation and future waveforms
  - **Variable superframe length** to provide required granularity for beam-hopping operation
- Format 5: Periodic BH and VLSNR
  - Strong preamble and header protection for cold acquisition and operation at SNR>-10dB
  - Enable **fragmentation** of frames
- Format 6: Traffic Driven BH and VLSNR
  - Long preamble to strengthen acquisition
  - Protection Level Indicator (PLI) to enable VLSNR support
  - No Fragmentation
- Format 7: Traffic driven, SNR>-3dB
  - Reduced overhead for higher SNR scenarios

Approved by DVB October 2019

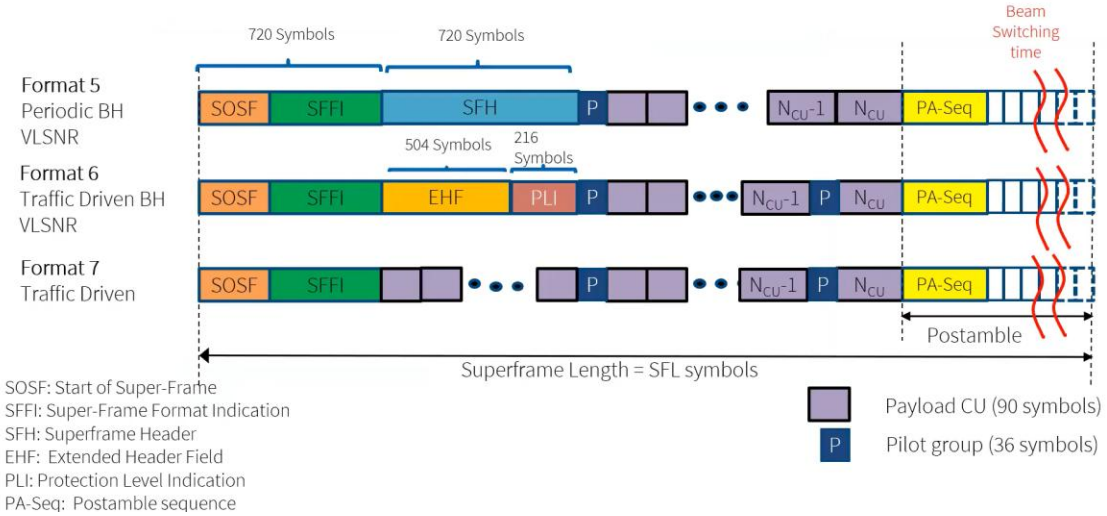
簡報項目	標準對應	說明與來源章節
Based on Annex E superframes	✔ 是	見 Annex E，定義 superframe 結構與長度變化
Supports multibeam operation and future waveforms	✔ 是	Annex E 明確支援多波束場景
Variable superframe length for beam-hopping granularity	✔ 是	Annex E 支援可變 superframe 長度以配合不同 BH 時間表
Format 5: Periodic BH and VLSNR support	✔ 是	附錄 E 定義 Format 5 為 periodic、適用於 SNR > –10dB
Format 6: Traffic Driven BH, VLSNR, long preamble, PLI	✔ 是	Format 6 描述於標準表格中，適用非週期性 BH 並使用 PLI
Format 7: Traffic Driven, reduced overhead, SNR > –3dB	✔ 是	Format 7 為簡化版波形，適用於高 SNR 條件

Annex E Superframe - Concept



簡報項目	標準對應性	說明與標準來源
Superframe 長度為 612540 symbols	✔ 是	見 Annex E.4，小節說明標準 superframe 長度
SOSF, SFFI, SFH, PLH 結構	✔ 是	見 Annex E.5，定義 superframe 開頭與 payload 排布
WH coded SOSF and Pilots	✔ 是	WH (Walsh-Hadamard) 編碼為支援干擾估計的標準機制
Fragmentation enabled by SFH pointer	✔ 是	SFH 包含 fragmentation 指標與指針，允許 BH 資料分片傳送
VLSNR 支援（modcods + PLI 指標）	✔ 是	Annex E.6 說明 VLSNR 對應編碼與 PLI 訊息欄位設計

DVB-S2X Waveforms for Beam Hopping Support
New Annex E Superframe Formats

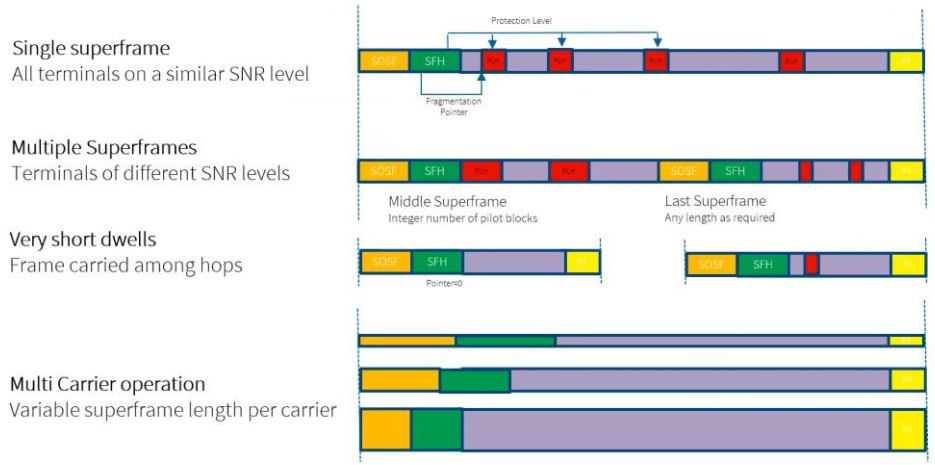


格式編號	名稱	特點	標準對應章節
Format 5	Periodic BH with VLSNR support	含 SFH（Superframe Header）、Pilot、具強前導及片段化支援	Annex E.6, Table E.3
Format 6	Traffic Driven BH with VLSNR	無 SFH，取而代之為 Extended Header Field (EHF) 及 Protection Level Indicator (PLI)	Annex E.6, Table E.3
Format 7	Traffic Driven BH (high SNR case)	更精簡設計，不含 EHF/PLI，降低開銷，適用於高 SNR 環境	Annex E.6, Table E.3

元件名稱	意義與標準依據
SOSF	Superframe 開始符，定義於 Annex E.5
SFFI	Superframe Format Indication，識別格式 5, 6, 7，定義於 Annex E.5
SFH	Superframe Header，格式 5 專屬，用於 fragmentation control
EHF	Extended Header Field，格式 6 引入，用於支援 BH 和同步參數
PLI	Protection Level Indicator，用於指定 Header 保護等級
PA-Seq	Postamble sequence，支援 beam switching 之 idle pattern
Pilot group (P)	同 Annex E.6 定義，用於 channel estimation
CU (90 symbols)	資料區塊單位（Codeword Unit）

Superframe Format 5 – Operation Cases

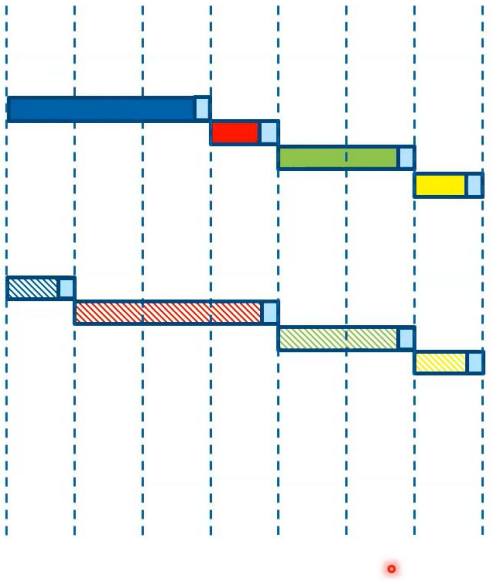
Full Flexibility to the System Designer



操作模式	說明	標準對應章節
Single Superframe	所有用戶端處於相似 SNR 水平。使用相同 PLI（Protection Level Indicator）進行保護配置。	Annex E.6.3
Multiple Superframes	用於不同 SNR 水平的終端，透過多個 superframe 承載，適配各自的保護等級（PLI）與 frame fragment。	Annex E.6.5
Very Short Dwells	適用於 beam hopping 極短停留時間（dwell），frame 可在不同 superframe 中斷續承載，pointer=0 表示無片段化。	Annex E.6.6
Multi Carrier Operation	支援不同 carrier 使用不同 superframe 長度與結構，應對頻寬與業務彈性配置需求。	Annex E.6.7

Grid Operation

- Hops take place only at an integer multiple of a basic time unit (the grid points)
- Advantages:
  - Ensure alignment of SF among beams
  - Reduces burst acquisition and time and increases acquisition reliability
- Disadvantages
  - Reduces flexibility in the choice of dwell time per cell



出處文件	是否提及 Grid Operation	核心描述與重點
ETSI **EN 302 307-2 Annex E**	✅ 是	定義 grid-based time plan：dwell time 為基準時間網格整數倍，以確保 beam switching 對齊(DVB)
ETSI TR 102 376-2 技術報告	✅ 是	詳述 grid 操作有助提升同步可靠性（burst acquisition、時間對齊）(ETSI, DVB)

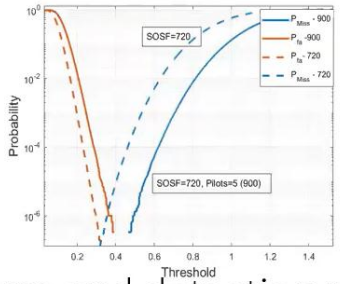
Purpose of Analysis and Simulation

Burst Reception Performance

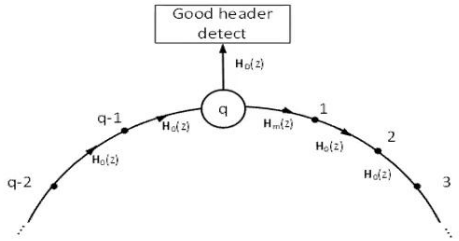
- Robust cold acquisition
  - Detection of the signal at SNR> -10dB
  - Short acquisition time
  - Essential estimation of timing, frequency, phase and SNR
- Robust cycle time learning (for the case of periodic beam hopping)
- Correct header decoding at SNR >-10dB
- Minimal degradation in performance
  - FER at tracking mode

模擬目標	標準中對應章節說明
Cold Acquisition @ SNR > -10 dB	EN 302 307-2 附錄 E：「Support for VL-SNR with PLI / WH-coded preambles」
Cycle Time Learning	TR 102 376-2：「Beam Hopping with Periodic Illumination」應考慮週期性結構
Header Decoding	EN 302 307-2：「PLH decoding robustness under VL-SNR」
Tracking Mode Performance	TR 102 376-2：「FER and header decoding ratio in tracking mode」

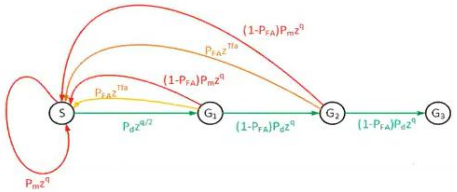
Burst Acquisition- Results



False Alarm and detection rates< 10^{-6}



Acquisition within a single hop time



Cycle learning within 2.5 dwells

Parameter Estimation:

- Time: 0.06 symbol time
- Frequency: 10^{-5} symbol rate
- SNR: 0.7 dB

📘 附錄 C：**Super-Framing structure**

- **C.4.2 Analysis and Simulations Results**（第 **169** 頁 起）
  - ✓ C.4.2.1 Signal Acquisition Time
  - ✓ C.4.2.2 Beam Hopping Cycle Time Acquisition
  - ✓ C.4.2.3 Parameter Estimation

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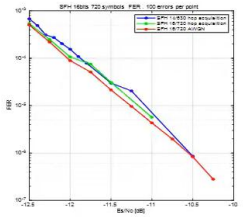
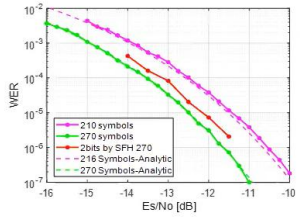
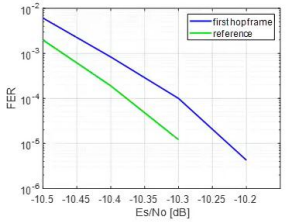
Information Detection- Results



SFH Detection (Format 5): WER<10^{-7}

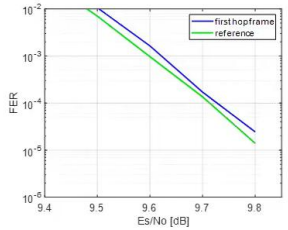


PLI Detection (Format 6): WER<10^{-7}



SNR degradation 0.07dB at VLSNR

Reference to continuous case



SNR degradation 0.02dB at High SNR

Reference to continuous case

- **Annex C: Super-Framing structure**
  - **C.4.2.4 Frame Error Rate Simulations**（第 **173** 頁 起）
    - ✓ 包含 SFH Detection（格式 5）
    - ✓ 包含 PLI Detection（格式 6）
    - ✓ 針對 VLSNR 及 High SNR 條件下的 SNR degradation

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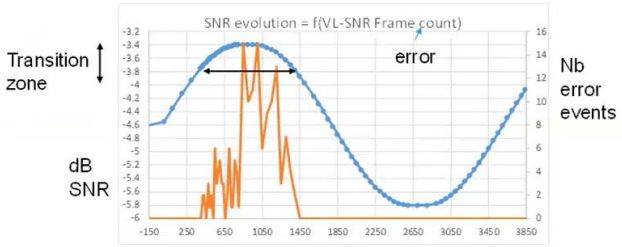
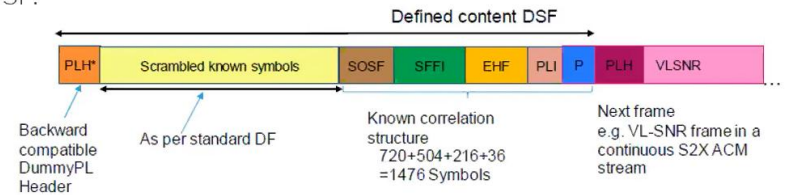
Maintenance

- The DVB-TM-S also took the opportunity or solve some problems which had been observed in the DVB-S2X
  - Co-existence of VLSNR frames with standard S2X frames.
    - Problem: Instability in transition zone between VLSNR and S2X MODCODs
    - Solution: Dummy Synchronisation Frame Same correlation structure as per new annex-E format 6.
    - VLSNR frames can now coexist in the same carrier as S2X frames thanks to DSF.





- **Annex B: DVB-S2X VL-SNR Modes**
  - **B.5 Dummy Synchronization Scheme (optional)**
    - **B.5.1 The problem scenario – 第 131 頁**
    - **B.5.2 Proposed Solution – 第 132 頁**
    - **B.5.3 Notes on using DSF – 第 133 頁**
    - **B.5.4 Conclusions – 第 133 頁**

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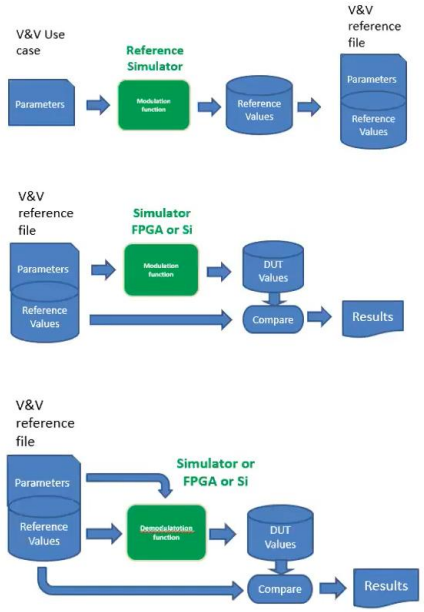
Continuity

- Alberto Morello retired from DVB-TM-S in December 2019
- Replaced by Vittoria Mignone (welcome).
  - The work continues

Further work

- Further work
  - Updating linked standards.
    - RCS, GSE, SI tables
    - To support Beam-Hopping
  - V&V: Verification and Validation
    - Test patterns
    - Common models
    - File exchange
      - Text based
      - Human and machine readable



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- **C.5 Example of Exploitation of the Superframing Structure: Precoding in Broadband Interactive Networks**
  第 **175–198** 頁

Concluding remarks

- The DVB-S standard now includes Beam-Hopping
  - All of the commercial requirements for Beam-Hopping have been met.
- This has been an excellent cooperation between multiple companies and institutions. We can be confident that we have a standard that is robust, forward looking and well maintained.

- **4.1.3 – Commercial requirements for the enhancements of the DVB-S2 standard to support beam hopping**
  頁數：第 **19** 頁
- **C.1.4.2 – Grid Operation**
  頁數：第 **147** 頁

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