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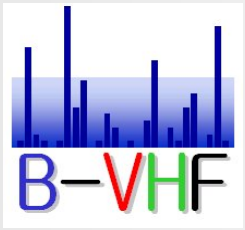

Technical and Operational Aspects of Migration Concepts of a broadband VHF Communication System (B-VHF)

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Overview

- Current VHF Band Situation
- B-VHF System
- Overlay Concept
- Transition Aspects
- Migration Scenarios
- Simulation Results
- Conclusions

Current VHF Band Situation

- VHF COM band (118-137 MHz) is essential for ATC
  - Today: narrowband systems with 25/8,33 kHz channel spacing
  - Frequency protected service volumes (co-channel interference reduction)
- Most VHF channels are used for analog ATS voice communication
  - One VHF frequency per ATC sector (some channels are used for AOC)
  - DSB-AM modulation / half duplex channel with ‘party line’ and PTT access
- Some 25 kHz channels are used for data link exchanges
  - ACARS data link (in Europe around 130MHz)
  - VDL Mode 2 & VDL Mode 4 at the top of the VHF spectrum

Existing narrowband systems effectively waste spectrum resources!

- VHF band is an attractive candidate for a new system
  - Good balance between cost of operations and radio coverage
  - Possibility to re-use existing ground infrastructure

System Concept and Technical Approach

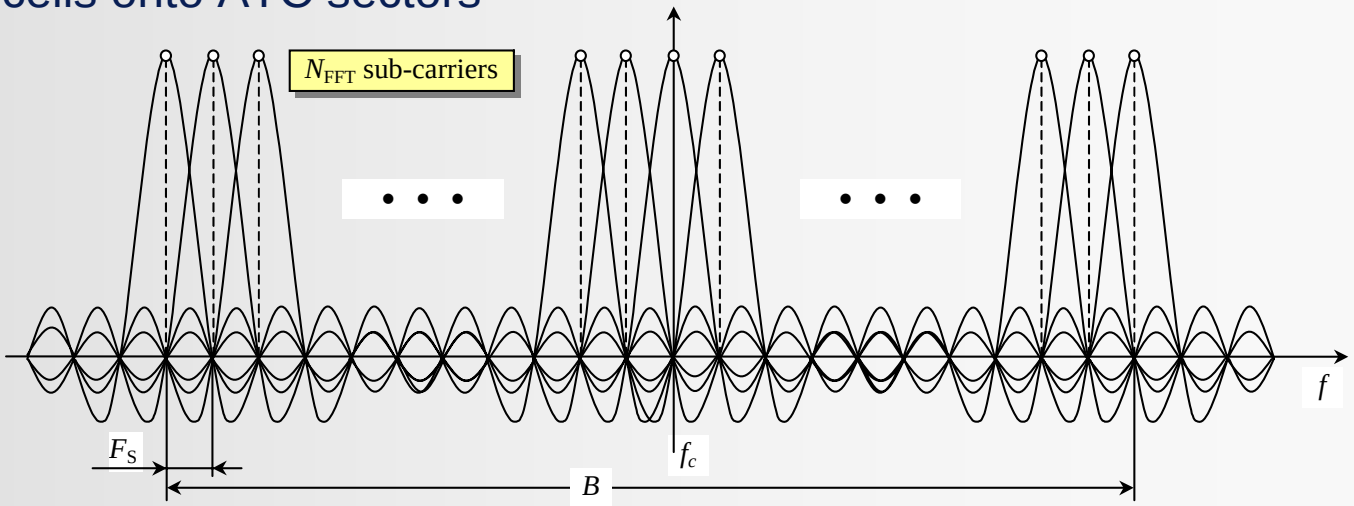
- What is B-VHF?
  - Broadband terrestrial cellular system based on highly efficient multi-carrier OFDM technology
  - Tailored for specific aeronautical needs
  - Integrated system, comprising voice and data link
  - Using CDMA for increased robustness

- Why multi-carrier approach?
  - The same approach is used by high-capacity bandwidth-efficient techniques (DAB, DVB-T, W-LAN, W-MAN)
  - COTS products are already available for standardized multi-carrier systems - 4G development will create additional re-usable components
  - OFDM enables in-band deployment (overlay concept)

B-VHF System (1) - B-VHF System Decisions

- Multi-Carrier (MC) system based on OFDM
  - Increased spectral efficiency
  - No continuous spectrum required
- Multi-user access technique
  - Forward link: CDMA with M&Q modification
  - Reverse link: OFDMA (mapping of OFDM sub-carrier groups to different user groups)
  - Duplexing scheme: Time Division Duplex (TDD)
- Relay-based communications architecture
- Mapping of B-VHF cells onto ATC sectors

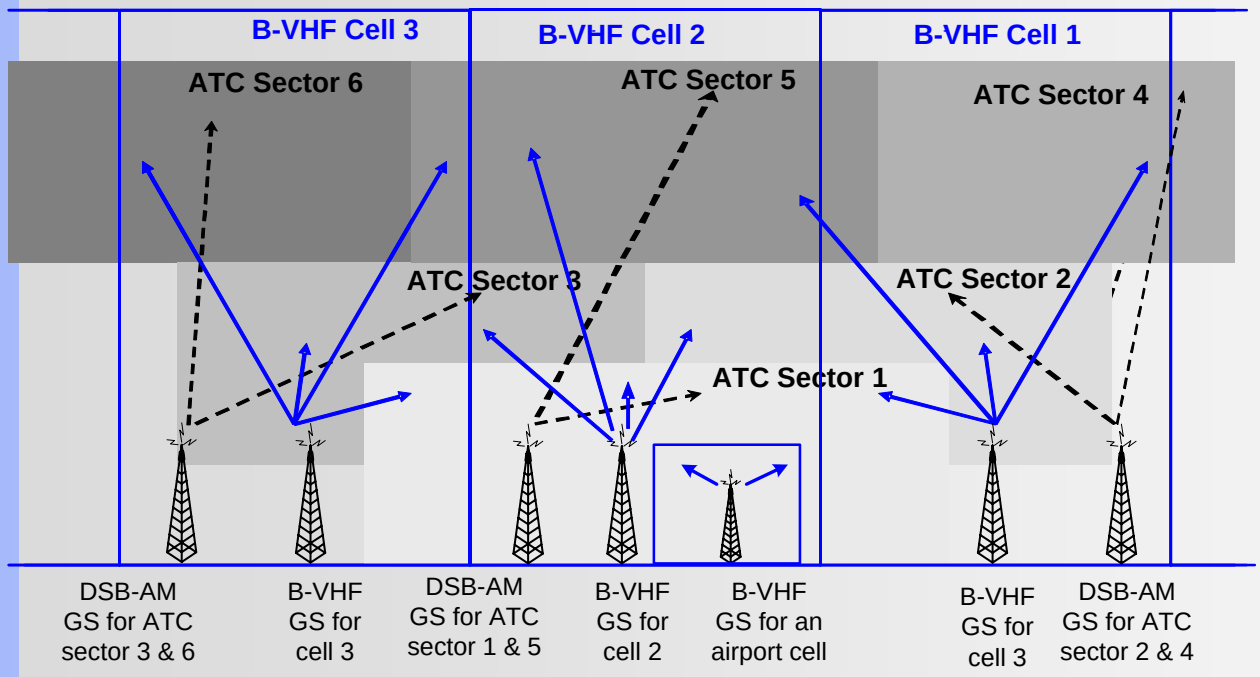
B : Bandwidth
F_S : Subcarrier Spacing
f_c : Carrier Frequency



B-VHF System (2) - Communication Concept

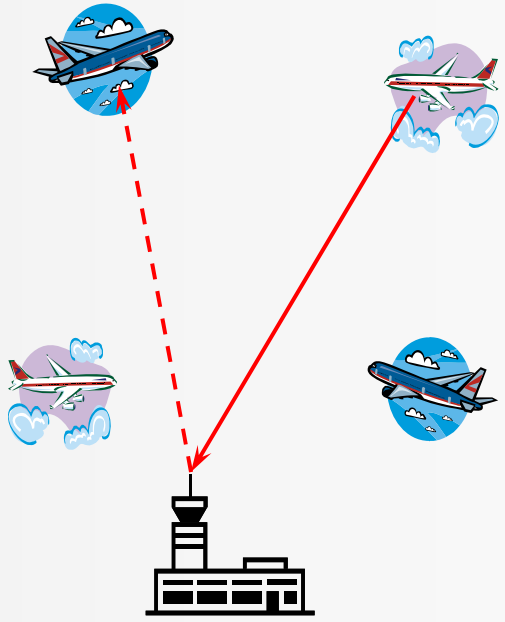
Cellular Concept

- One B-VHF cell might provide coverage for several ATC sectors
- One ATC sector might belong to several B-VHF cells



Ground station supported communications

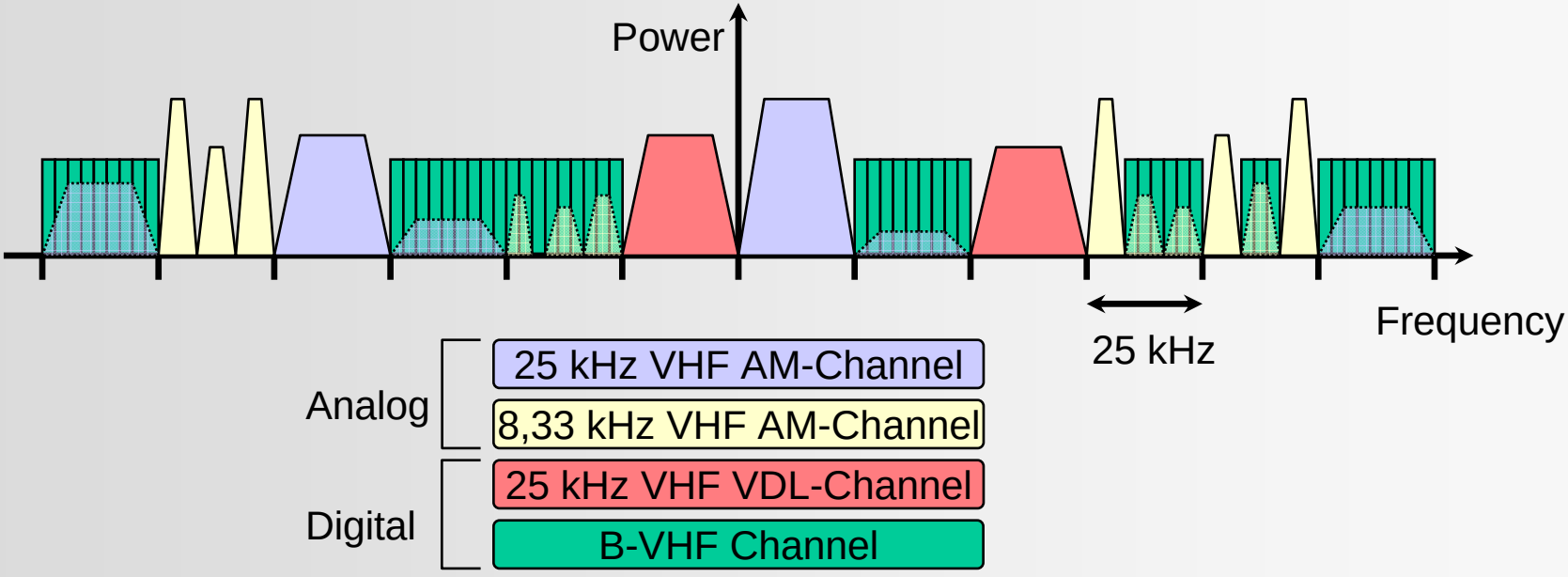
Air-Air Communication (Voice+Data) via GS Retransmission



Ground Station (GS)

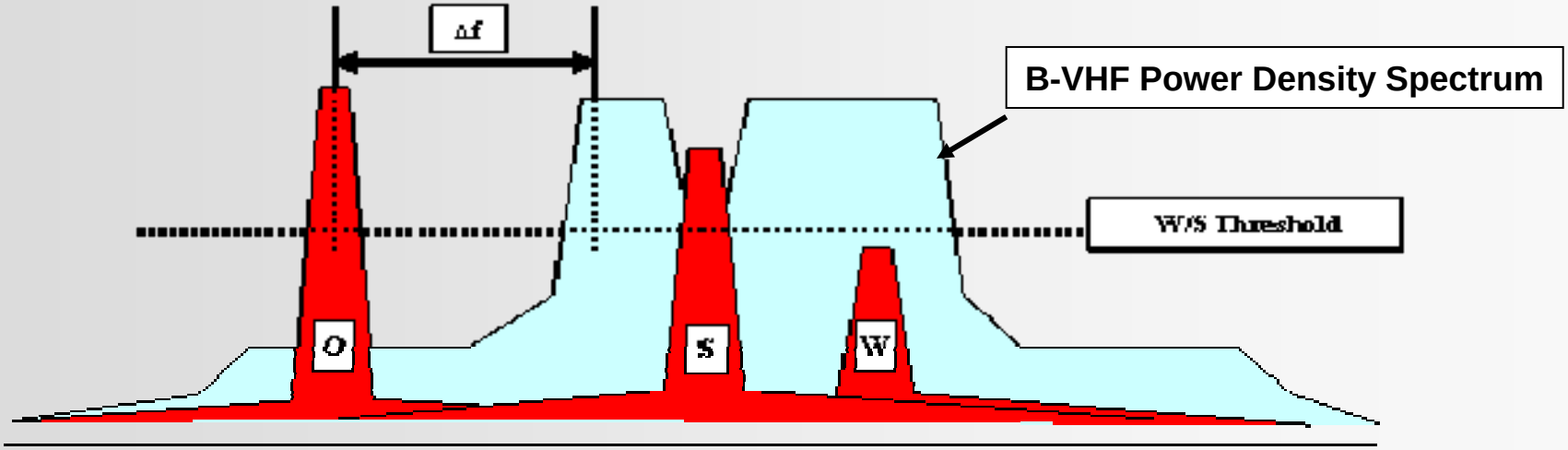
Overlay Concept (1)

Channel allocation remains unchanged for DSB-AM & VDL channels
'Distant' VHF channels can be locally re-used for the new B-VHF system
'Old' DSB-AM / VDL equipment remains untouched



Overlay Concept (2)

- S" constellation denotes a STRONG NB in-band signal with a power above WEAK/STRONG threshold - channels classified as "S" are not used by the B-VHF system.
- "W" constellation denotes a WEAK in-band NB signal within the B-VHF RF bandwidth but is received with a power below the WEAK/STRONG threshold - channels are used by the B-VHF system
- O" constellation denotes a NB signal (channel) that operates outside the B-VHF RF bandwidth



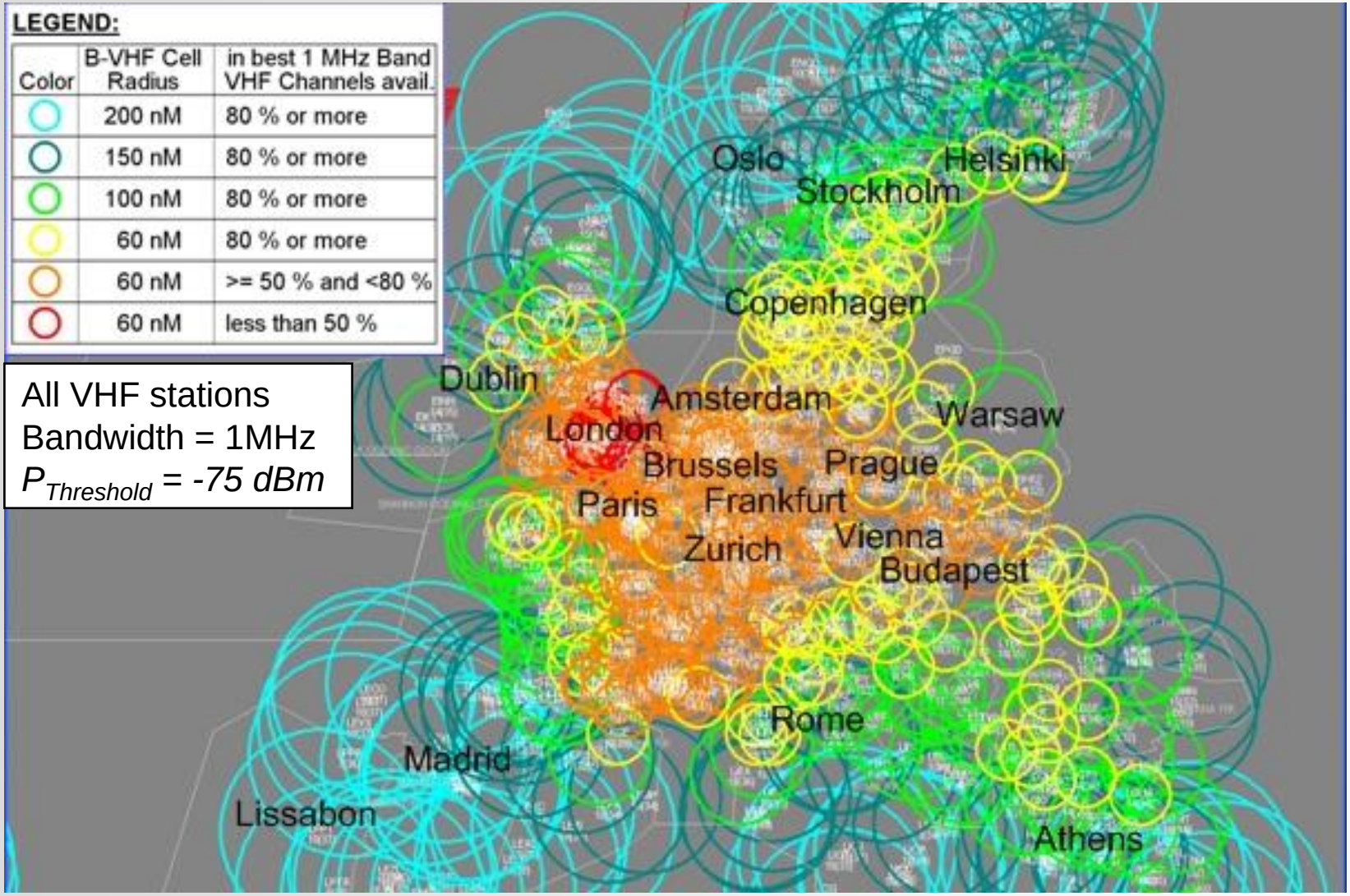
Transition Aspects

- Aeronautical bands for a future aeronautical communications system
  - **VHF COM range** (118–137 MHz)
  - **VOR range** (target range: 116–118 MHz)
  - **DME range** (target range: 960–1024 MHz)
  - **MLS range** (target range: 5091–5150 MHz)
- Deployment mode of the airspace
  - **B-VHF-supported airspace:** B-VHF ground infrastructure deployed, but B-VHF airborne equipment is voluntary
  - **B-VHF airspace**: B-VHF ground infrastructure and B-VHF aircraft equipment is mandatory
  - **NB airspace**: no ground B-VHF system is deployed
- Spectrum Usage Options
  - **Overlay approach**: B-VHF system shares the spectrum with other systems
  - **Dedicated channels**: Other systems operate “out-band” with respect to the B-VHF broadband channel -> no spectrum sharing

Migration Scenarios

- **VHF-COM Transition**: B-VHF System Deployment in the VHF COM band
  - provides an integrated voice/data system.
  - deployment scenario is based on overlay; simultaneous usage of both systems in the whole airspace (B-VHF-supported airspace)
  - no modification on the existing system
- **VHF-COM-DME Transition:** B-VHF System Deployment in the VHF & DME band
  - operates as an integrated voice/data system
  - partly overlay character
    - Overlay system in the VHF band; with simultaneous usage of both systems
    - Usage of dedicated channels In the DME band
  - approach and tower VHF channels are transferred to the DME band
- **VHF-COM-NAV Transition**: B-VHF System Deployment in the VHF NAV & COM band
  - similar features as the VHF- COM-DME Transition approach
  - only the available bandwidth is smaller the VHF NAV band than in the DME band

Cell Assignment for -75 dBm Threshold with all VHF stations (1MHz)

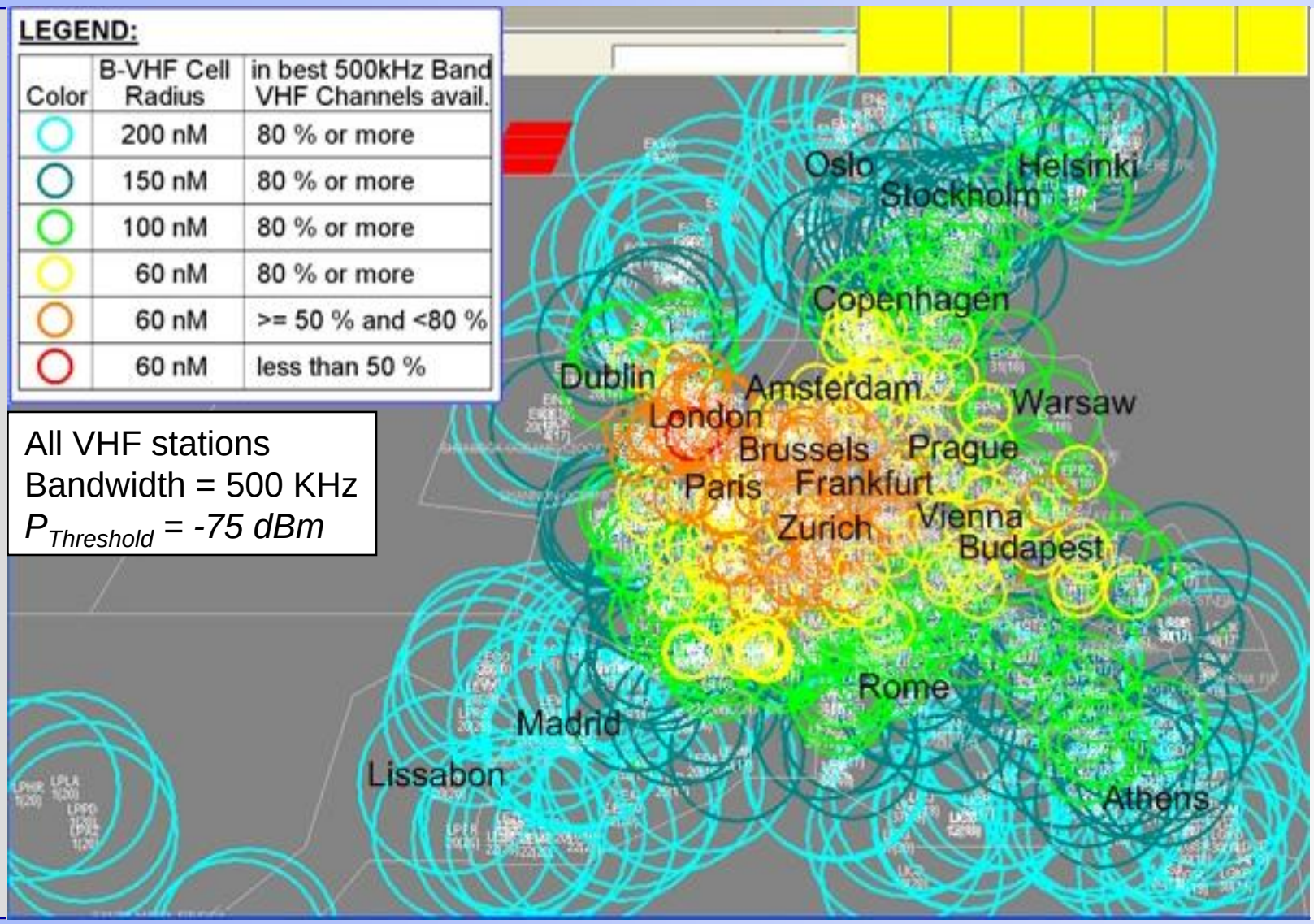


Cell Assignment for -75 dBm Threshold with all VHF stations (500 KHz)

LEGEND:

Color	B-VHF Cell Radius	in best 500kHz Band VHF Channels avail.
	200 nM	80 % or more
	150 nM	80 % or more
	100 nM	80 % or more
	60 nM	80 % or more
	60 nM	>= 50 % and <80 %
	60 nM	less than 50 %

All VHF stations
Bandwidth = 500 KHz
$P_{Threshold}$ = *-75 dBm*

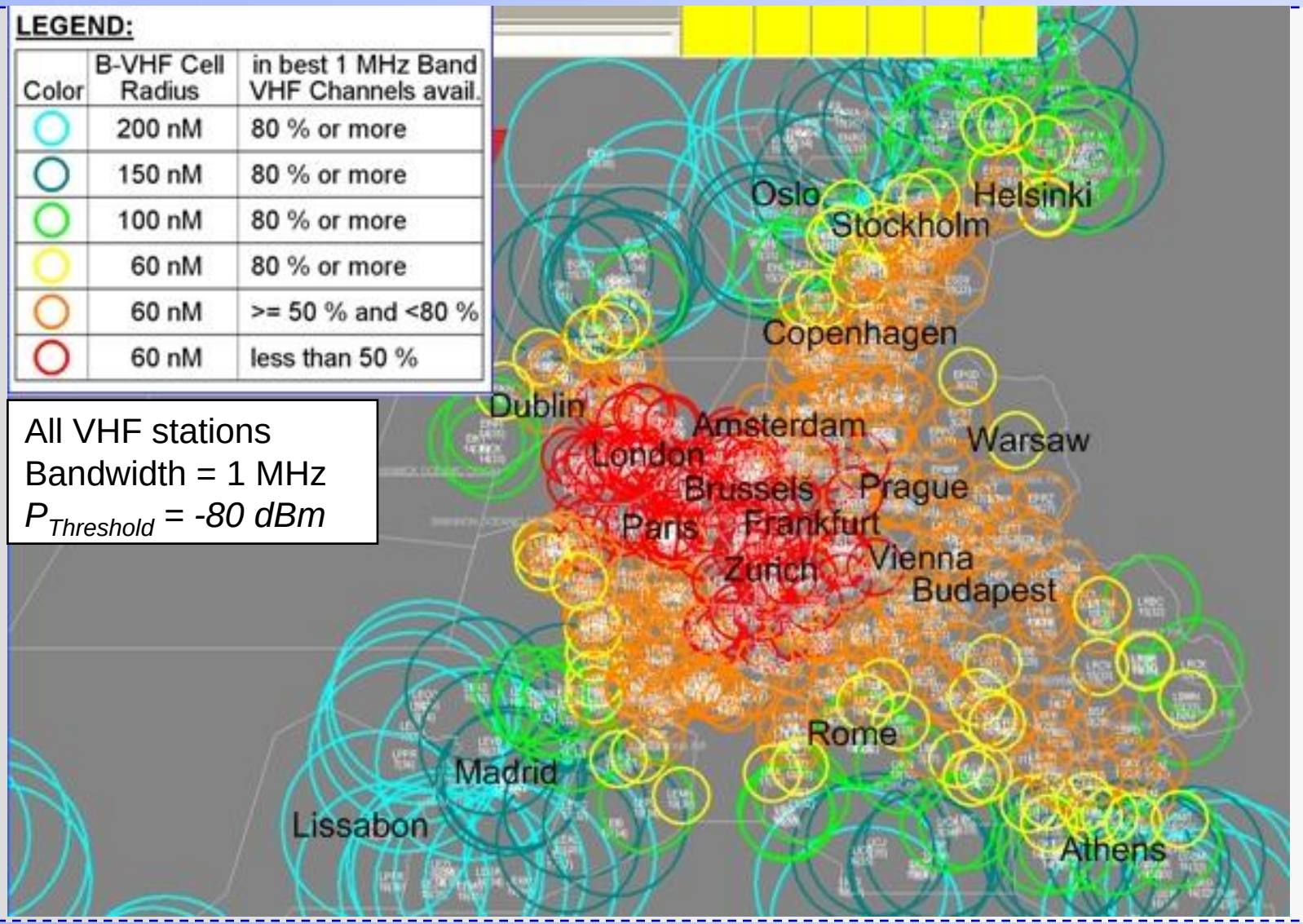


Cell Assignment for -80 dBm Threshold with all VHF stations (1 MHz)

LEGEND:

Color	B-VHF Cell Radius	in best 1 MHz Band VHF Channels avail.
	200 nM	80 % or more
	150 nM	80 % or more
	100 nM	80 % or more
	60 nM	80 % or more
	60 nM	>= 50 % and <80 %
	60 nM	less than 50 %

All VHF stations
Bandwidth = 1 MHz
$P_{Threshold}$ = *-80 dBm*

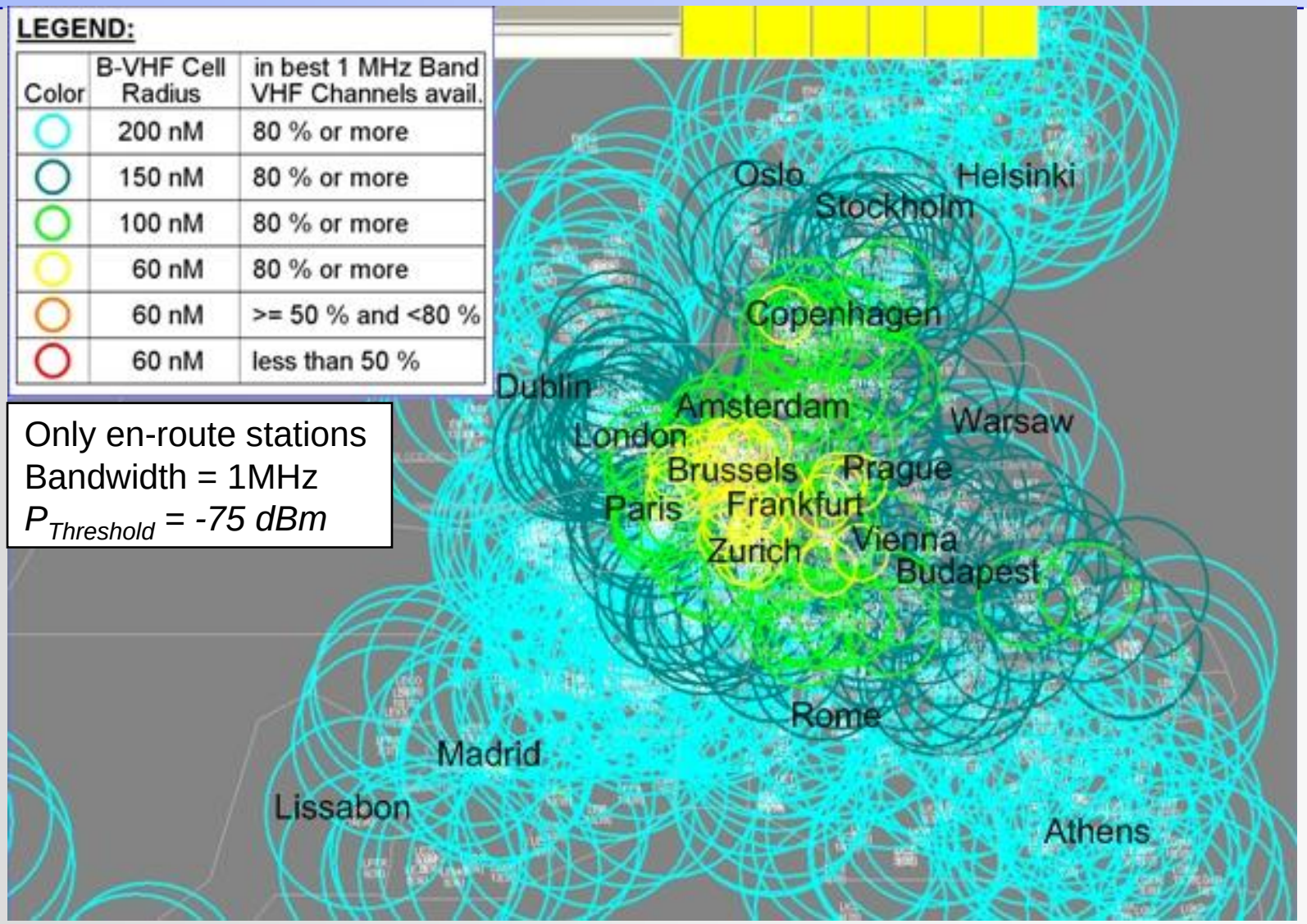


Cell Assignment for -75 dBm Threshold with only en-route stations (1 MHz)

LEGEND:

Color	B-VHF Cell Radius	in best 1 MHz Band VHF Channels avail.
	200 nM	80 % or more
	150 nM	80 % or more
	100 nM	80 % or more
	60 nM	80 % or more
	60 nM	>= 50 % and <80 %
	60 nM	less than 50 %

Only en-route stations
Bandwidth = 1MHz
$P_{Threshold}$ = *-75 dBm*

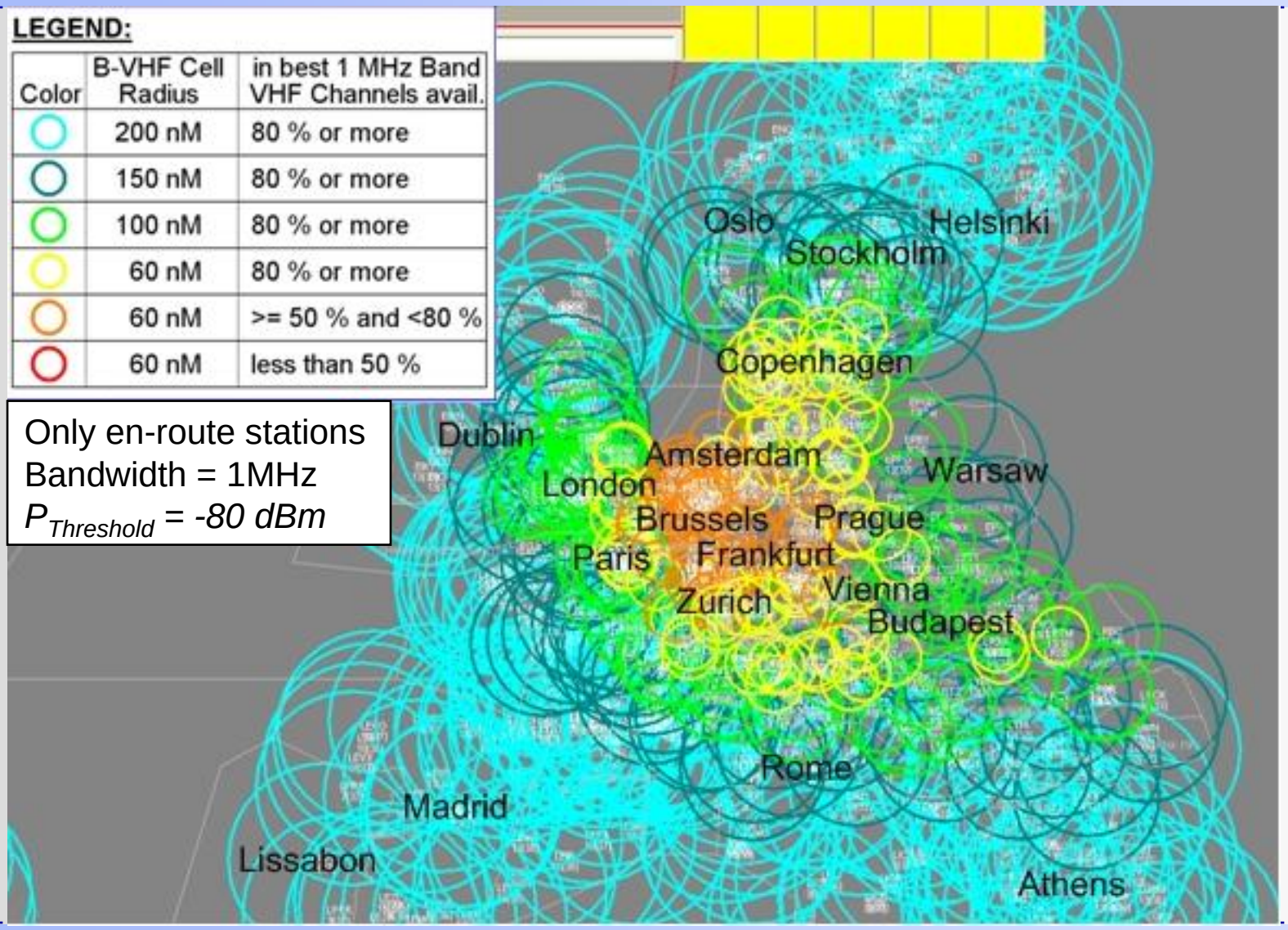


Cell Assignment for -80 dBm Threshold with only en-route stations (1 MHz)

LEGEND:

Color	B-VHF Cell Radius	in best 1 MHz Band VHF Channels avail.
	200 nM	80 % or more
	150 nM	80 % or more
	100 nM	80 % or more
	60 nM	80 % or more
	60 nM	>= 50 % and <80 %
	60 nM	less than 50 %

Only en-route stations
Bandwidth = 1MHz
$P_{Threshold}$ = *-80 dBm*

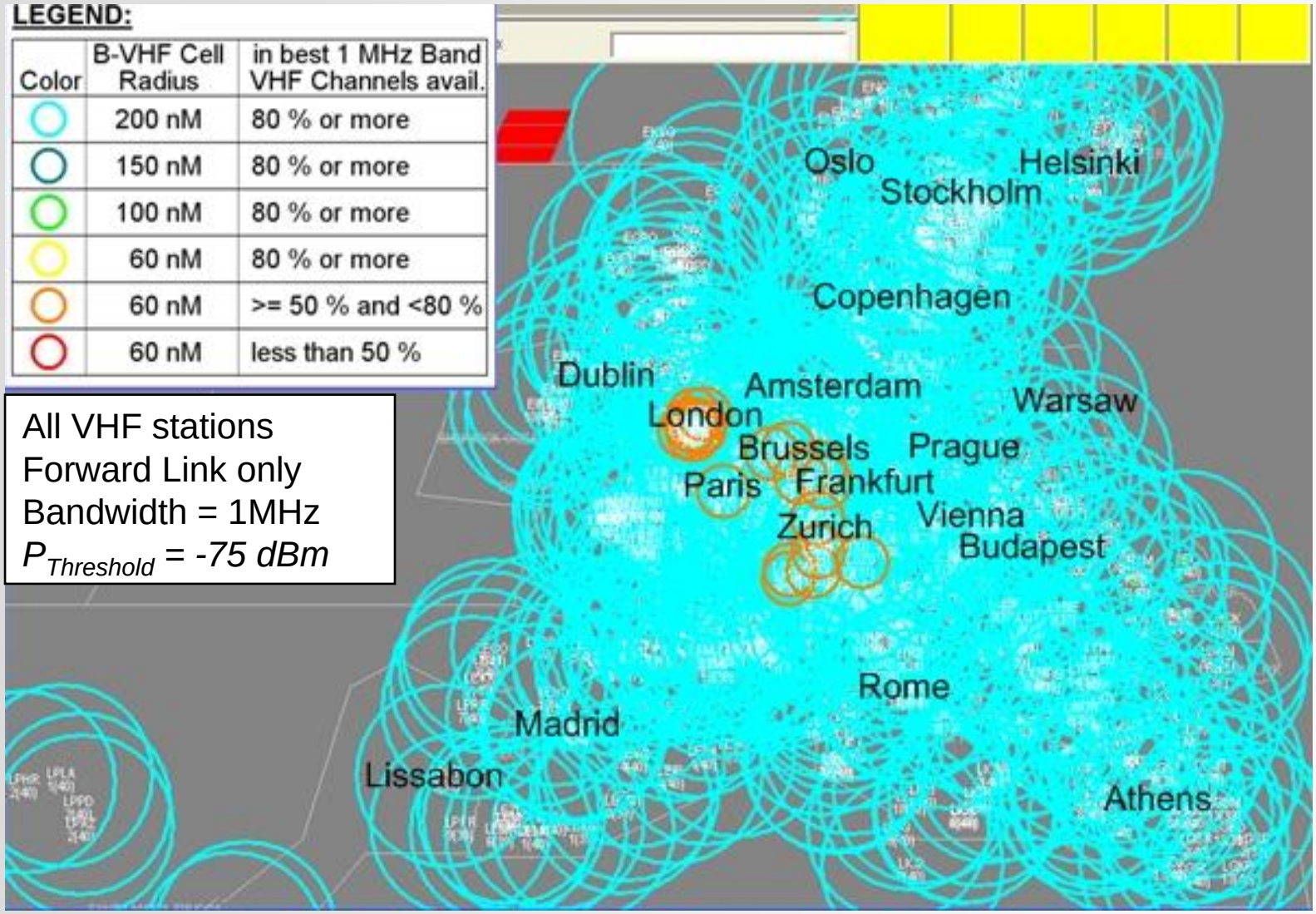


Forward Link cell sizes for -75 dBm Threshold with all VHF stations (1 MHz)

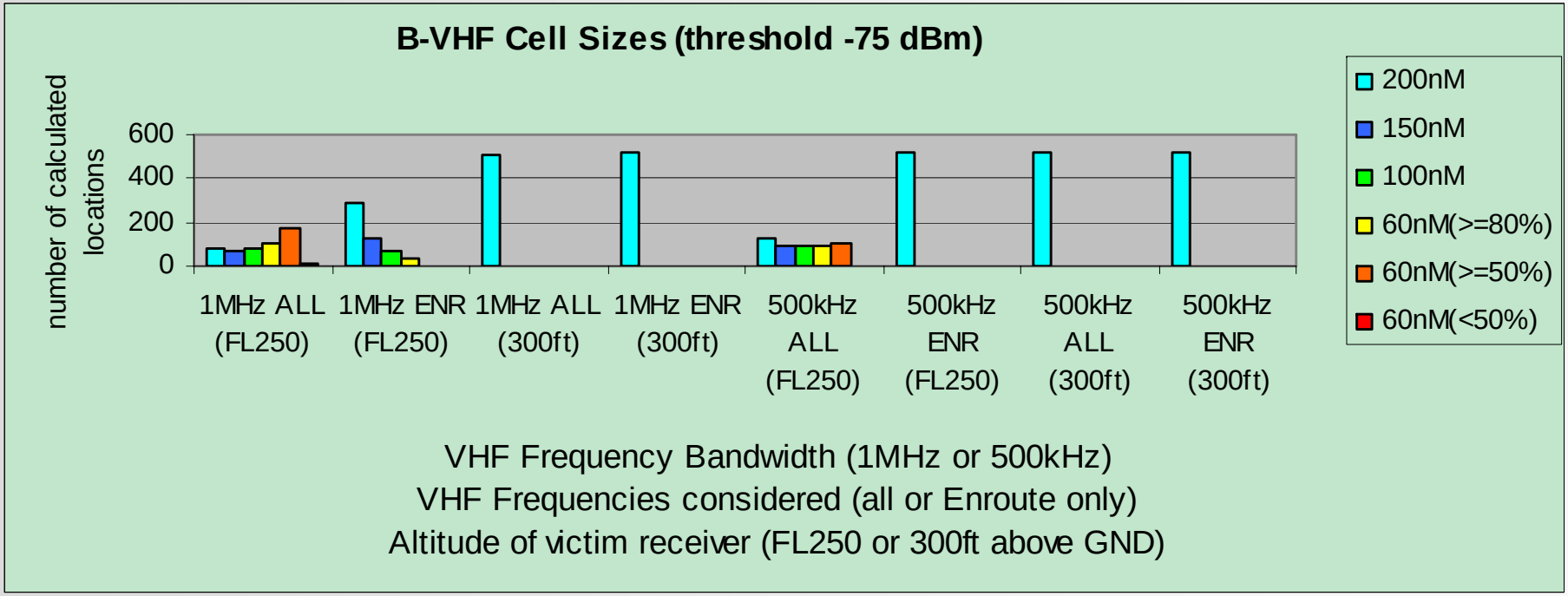
LEGEND:

Color	B-VHF Cell Radius	in best 1 MHz Band VHF Channels avail.
	200 nM	80 % or more
	150 nM	80 % or more
	100 nM	80 % or more
	60 nM	80 % or more
	60 nM	>= 50 % and <80 %
	60 nM	less than 50 %

All VHF stations
Forward Link only
Bandwidth = 1MHz
$P_{Threshold}$ = *-75 dBm*



B-VHF cell size distribution



Conclusions

- **VHF-COM Transition:**
  - Feasible for a threshold value of -75 dBm!
  - Changes of the existing system in small areas necessary (for Europe)
  - High effort to suppress narrowband interference within the B-VHF receiver
  - Compared to other transition scenarios lower system capacity of the B-VHF system
  - Instead of simultaneous usage of both systems (B-VHF-supported airspace**)** -> simultaneous conversion of large airspaces (B-VHF airspace)
- **VHF- COM - DME Transition and VHF- COM - NAV Transition :**
  - Feasible for a threshold value of -75 dBm and -80 dBm
  - Lower interference within the B-VHF receiver (Compared to VHF-COM Transition)
  - Easier initial deployment and higher system capacity (Compared to VHF-COM Transition)
  - VHF band still used for en-route cells -> macro cells for the coverage and micro cells in communication intensive areas (e.g. airport) for the system capacity
  - For the DME band changes in the physical layer of the B-VHF system necessary (e.g. B.VHF RF front-end)

Thank you for your attention!

Any Questions?