RF coverage and interference planning

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Technical Committee

RF Coverage and interference

Coverage requirements

Field strength reference levels

Transmission network considerations

SFN design and performance

Planning and Interference

Case study

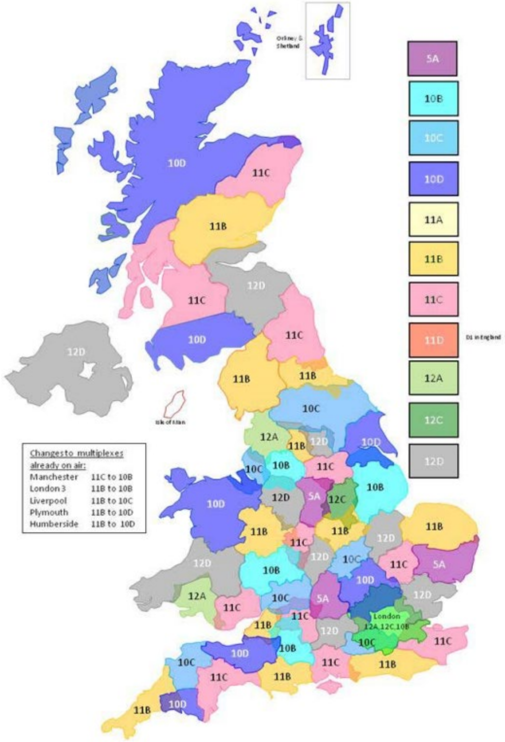
Requirements

High level requirements

Coverage areas are usually defined by the country's Broadcasting Regulator

- Wide area broad targets e.g. 90% of country area or 95% of country population
- Specific coverage requirements
  - Licence Area Plans (LAPs)
  - Cities, towns, roads
  - Radio station target audience
- Coverage is often planned to be implemented in phases – usually the highest population areas first

UK channel allotments



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Requirements

Capacity

How many services both now and later will be required in each area

- Defines how much spectrum is needed
- E.g. Sydney uses 3 ensembles (5.136MHz) for approx 63 services

Typically dimensioned for 64 kbps per service including PAD

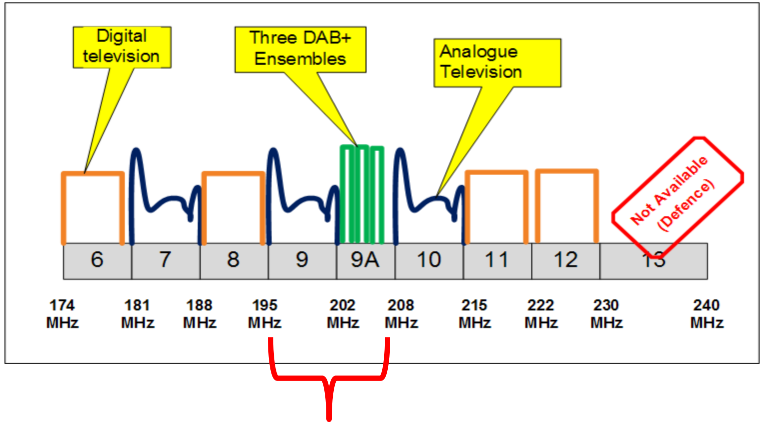
Requirements

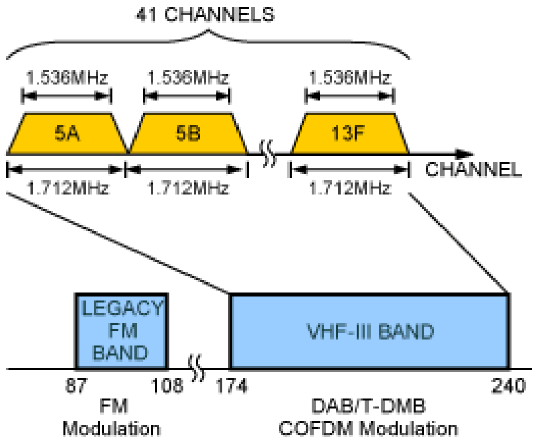
Spectrum

How much of VHF Band III is available?

Cross border coordination impact

Spectrum reuse, typical cellular design requires 3-5 times single cell capacity dependant on terrain and coverage requirements





2 DTV channels allocated

14MHz = 8 DAB channels = 8A, B, C, D, 9A, B, C, D

Requirements

Germany

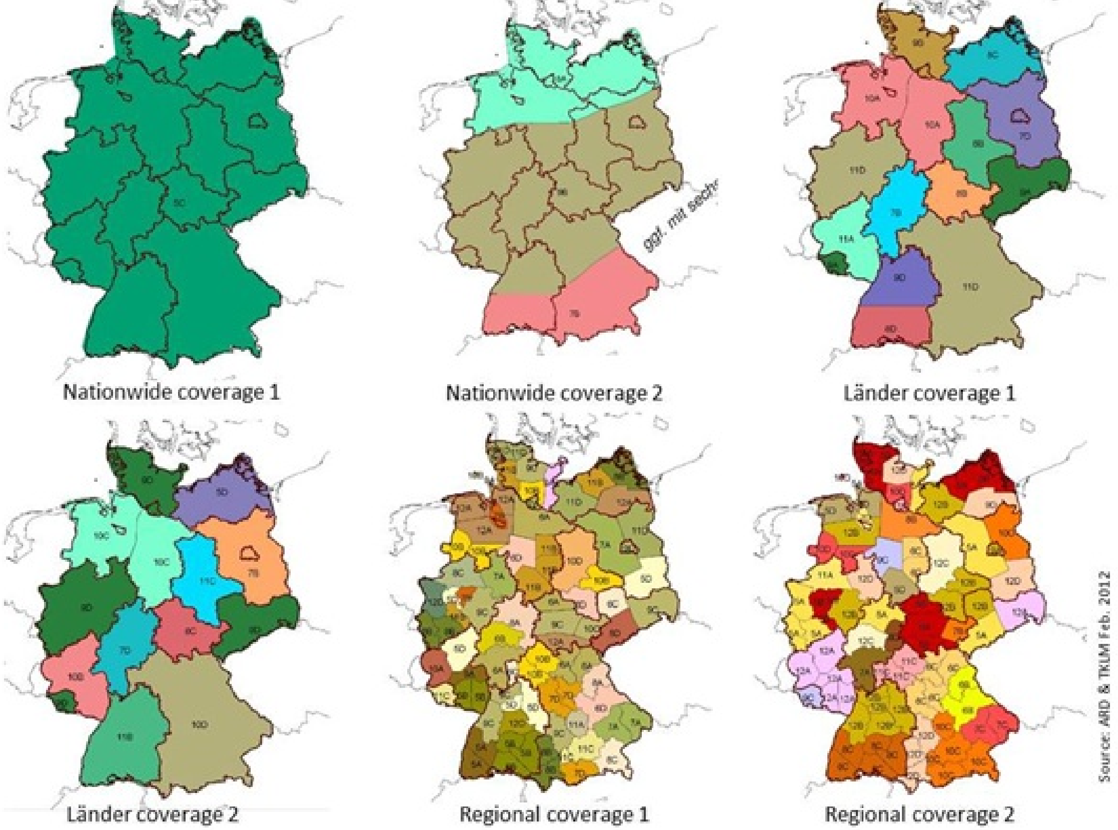
Full VHF Band III

MFN and SFN

SFNs are usually contained within a larger MFN structure

Still requires frequency coordination with neighbouring countries

National SFN | Sub-National SFNs | MFN



Field strength reference levels

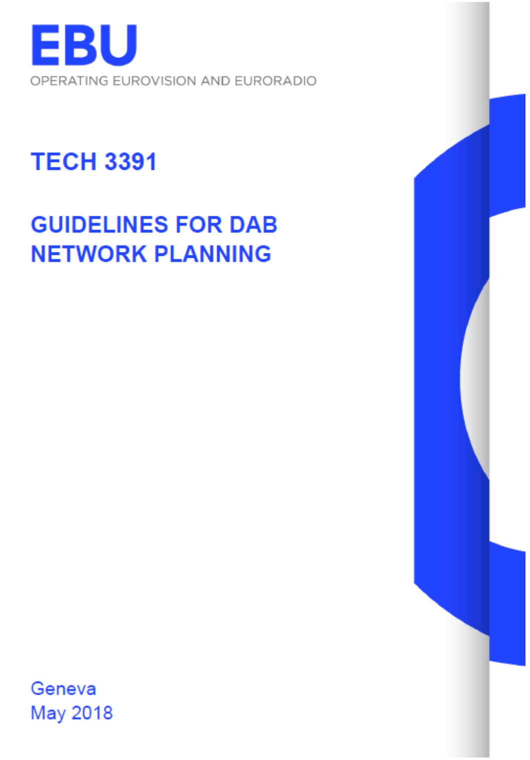
Coverage Targets

Reception modes from vehicle to urban

Guidelines for DAB network planning — Tech 3391

Table 9: Summary of reception modes considered in this report

	Reception mode	Channel model		Receiver type	Antenna Type*	High speed 120 km/h
1	Mobile reception (MO)	Rural	RA 6	Mounted inside the car and connected to the car antenna	Mounted outside the vehicle	Yes
2	Portable outdoor reception (PO)	Urban/ Suburban	TU 12	Stand-alone (table top or kitchen type)	Built-in (folded or telescopic)	No
3	Portable indoor reception (PI)	Urban/ Suburban	TU 12	Stand-alone (table top or kitchen type)	Built-in (folded or telescopic)	No
4	Handheld portable outdoor reception (PO-H/Ext)	Urban/ Suburban	TU 12	Handheld (e.g. smartphone type)	External (e.g. wired headset or telescopic)	No
5	Handheld portable indoor reception (PI-H/Ext)	Urban/ Suburban	TU 12	Handheld (e.g. smartphone type)	External (e.g. wired headset or telescopic)	No
6	Handheld mobile reception (MO-H/Ext)	Rural	RA 6	Handheld (e.g. smartphone type)	External (e.g. wired headset or telescopic)	Yes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GUIDELINES FOR DAB NETWORK PLANNING

Geneva
May 2018

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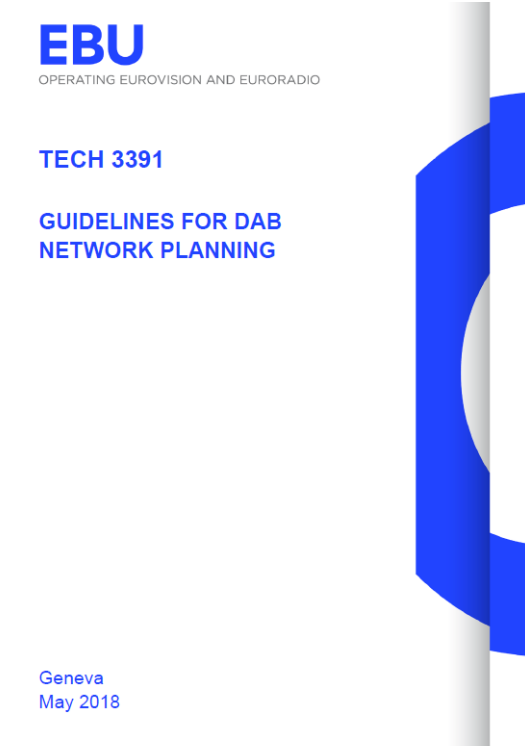
Field strength reference levels

Coverage Targets

Minimum field strength for each reception mode depends on many variables

- Location variation
- Man Made Noise
- Antenna gain
- Receiver performance / Noise Figure
- Building entry loss
  - Building types and density have significant impact
  - Ground level vs high levels, opposite side of building
- Cars generally OK if in-building performance is satisfactory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Field strength reference levels

Table 24: DAB+ in Band III

			1. (MO) Mobile / rural	2. (PO) Portable outdoor /suburban	3. (PI) Portable indoor / urban
Frequency	Freq	MHz	200	200	200
Minimum C/N required by system	C/N	dB	12.6	11.9	11.9
Receiver noise figure	F_r	dB	6	6	6
Equivalent noise bandwidth	B	MHz	1.54	1.54	1.54
Receiver noise input power	P_n	dBW	-136.10	-136.10	-136.10
Min. receiver signal input power	$P_{s\,min}$	dBW	-123.50	-124.20	-124.20
Min. equivalent receiver input voltage, 75Ω	U_{min}	dBµV	15.25	14.55	14.55
Feeder loss	L_f	dB	0	0	0
Antenna gain relative to half dipole	G_d	dB	-5	-8	-8
Effective antenna aperture	A_a	dBm^2	-10.32	-13.32	-13.32
Min Power flux density at receiving location	Φ_{min}	$dB(W)/m^2$	-113.18	-110.88	-110.88
Min equivalent field strength at receiving location	E_{min}	dBµV/m	32.62	34.92	34.92
Allowance for man-made noise	P_{mmn}	dB	0.90	1.50	5.30
Entry loss (building or vehicle)	L_b, L_v	dB	0	0	10.50
Standard deviation of the entry loss		dB	0	0	8.20
Location probability		%	90	70	70
Distribution factor			1.28	0.52	0.52
Standard deviation[17]			4	4	9.12
Location correction factor	C_l	dB	5.12	2.08	4.74
Minimum median power flux density at 1.5m a.g.l.; 50% time and 50% locations (for a location probability of 90 or 70% as indicated)	Φ_{med}	$dB(W)/m^2$	-107.16	-107.30	-90.34
Minimum median equivalent field strength at 1.5m a.g.l.; 50% time and 50% locations (for a location probability of 90 or 70% as indicated)	E_{med}	dBµV/m	38.64	38.50	55.46
Location probability		%	99	95	95
Distribution factor			2.33	1.64	1.64
Standard deviation			4	4	9.12
Location correction factor	C_l	dB	9.32	6.56	14.96
Minimum median power flux density at 1.5m a.g.l.; 50% time and 50% locations (for a location probability of 99 or 95% as indicated)	Φ_{med}	$dB(W)/m^2$	-102.96	-102.82	-80.12
Minimum median equivalent field strength at 1.5m a.g.l.; 50% time and 50% locations (for a location probability of 99 or 95% as indicated)	E_{med}	dBµV/m	42.84	42.98	65.68

Field strength reference levels

Planning field strengths summary

Rx height = 1.5m

Unofficial – for reference purposes only

Planning field strengths (dBµV/m)				
:	Mobile outdoor	Sub Urban	Urban	Dense Urban
Australian planning field strength	50	54	60	70
EBU Tech 3391 planning field strength	42.8	43	65.7	

Differences mainly due to assigned antenna gain and MMN level

Tech 3391 is for Portable Outdoor rather than Suburban Indoor

Building entry loss adds over 10.5 dB

Transmission network considerations

High Power High Tower (HPHT) v Low Power Low Tower selections (LPLT)

- Higher sites will always provide greater coverage due to increased line-of-sight areas
- Terrain is the largest impact on coverage area, large buildings are equivalent to hills!
- Uneven and shadowed terrain requires increased main site power and/or increased repeaters

Type	Power (kW ERP)	Typical height above served area (m)	Best use
HPHT	10 - 50+	>100	wide area coverage but may experience shadowed areas especially in the distant coverage areas
MPMT	2 - 10	30-100	undulating areas with no high transmission site
LPLT	0.1 - 2	<30	local area coverage

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Transmission network considerations

HPHT – LPLT Cost implications

- HPHT are generally preferred for wide area coverage
  - will usually give best coverage kms^2/$
- Repeater sites are often LPLT to cover specific areas
  - City sites can be very expensive, even for LPLT
  - High population density drives prices up even for sites like water towers
  - Telco towers are often too low!
- Site costs are often the largest component of Opex for main AND repeaters
- Site selection for cost optimisation is time consuming – especially for multiple repeater sites in large cities
- The number of main HPHT sites in large cities are often limited

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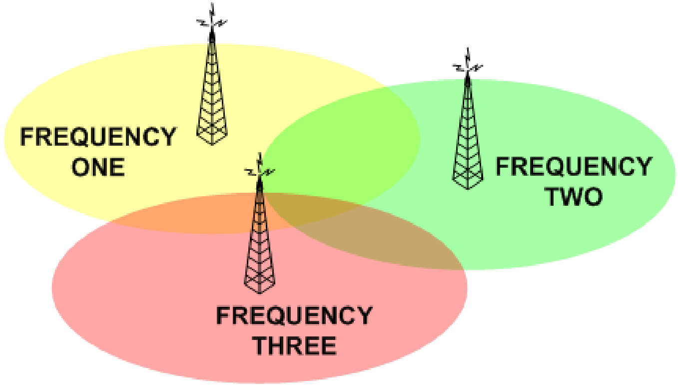
Transmission network considerations

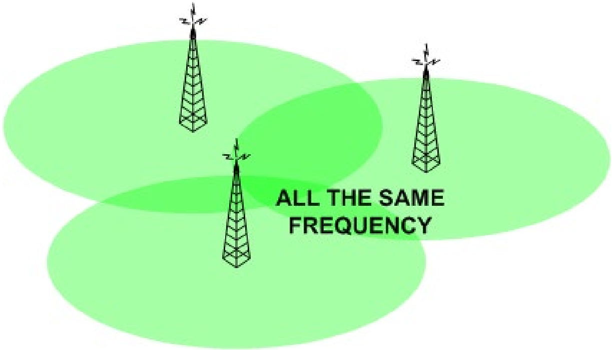
Multi-Frequency Networks (MFN) and Single Frequency Networks (SFN)

MFN
Multiple different multiplexes



All transmitters can deliver different content to the area concerned

SFN
Main Tx and 2 Gap Fillers



All transmitters must deliver the same content to the area concerned

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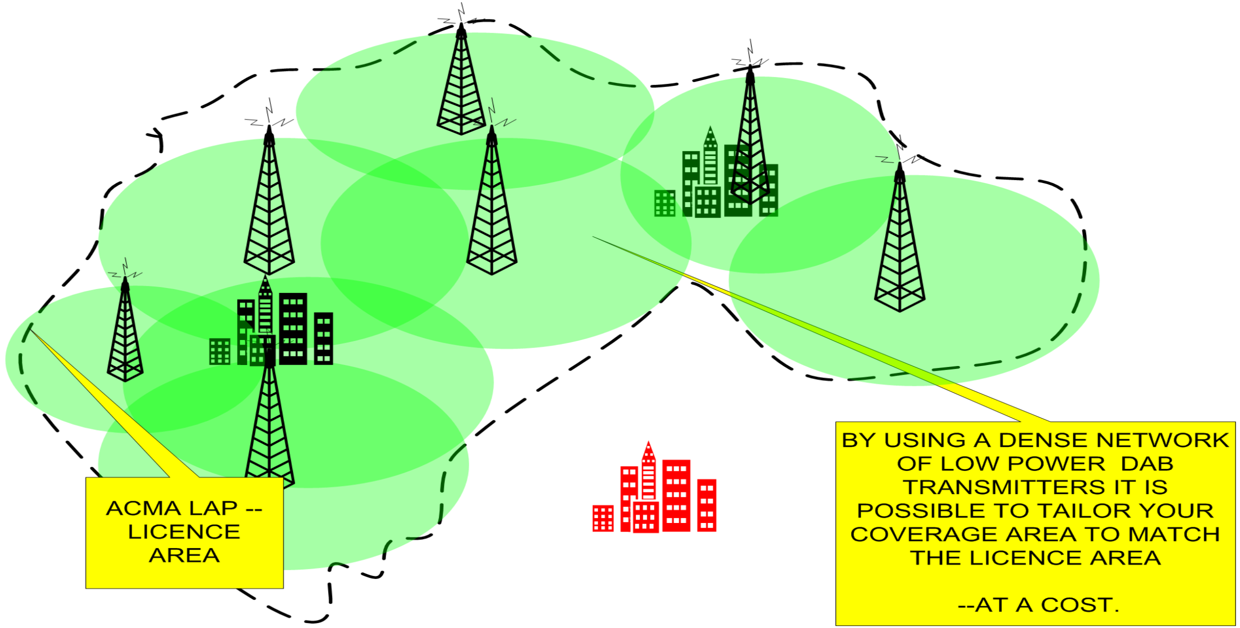
Transmission network considerations

Covering a specific area, e.g. a Licence Area

High spectral efficiency



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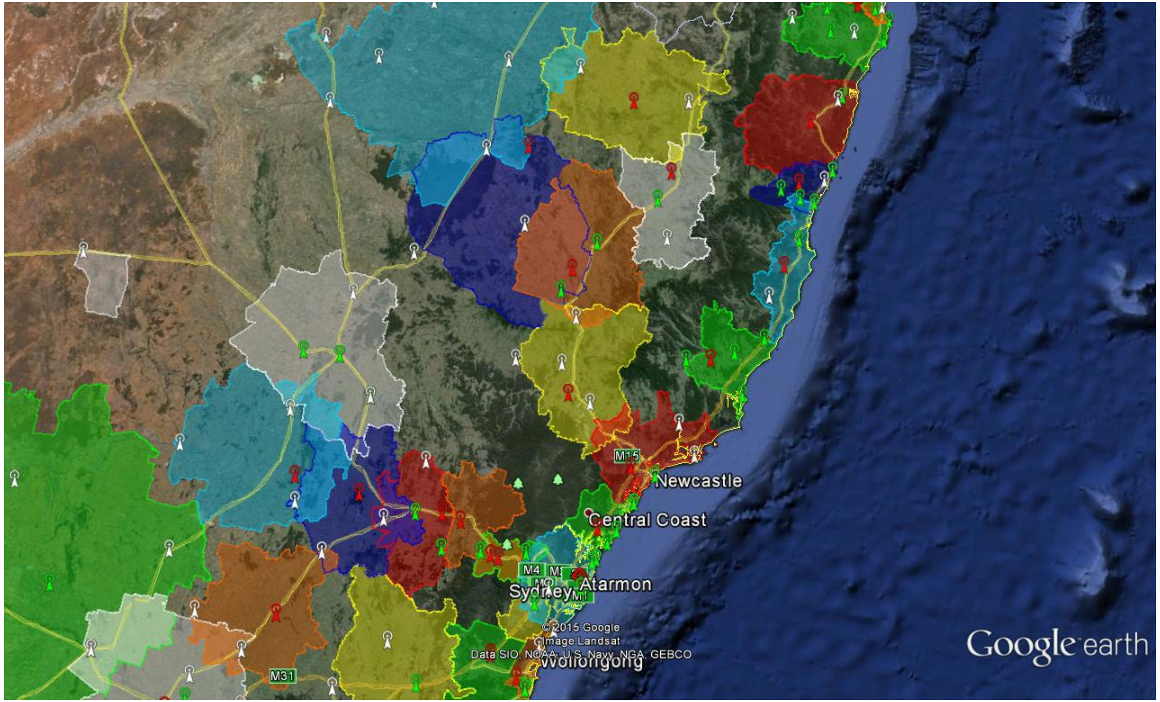
Transmission network considerations

Commercial licence areas - Northern NSW example

Each licence area has its own local content and SFN to ensure appropriate coverage



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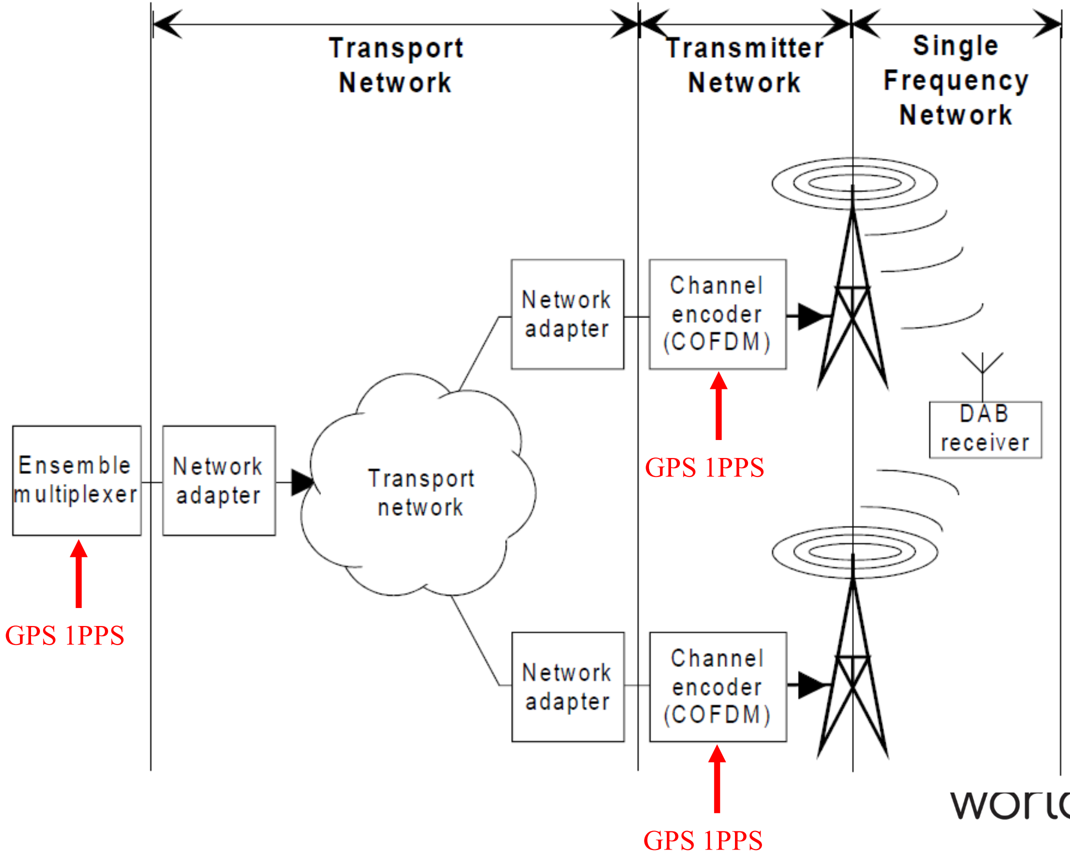
Single Frequency Networks

The DAB SFN model

ETS 300 799



SFN timing

The transmission launch time is controlled by the TImeSTamp (TIST) parameter in the ETI stream.

All transmitters in an SFN must be time aligned

The multiplex embeds a TIST time stamp in each ETI frame which defines the time it is assembled relative to a coordinated timing reference, e.g. 1PPS

All transmitters are required to be aligned to a 1PPS timing signal derived from GPS/Glonass

Some adjustment of the maximum operating distance and hence the area which may experience interference can be made using the transmission delay of individual transmitters

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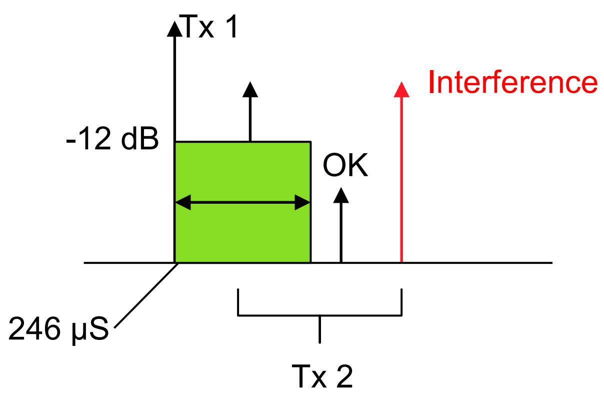
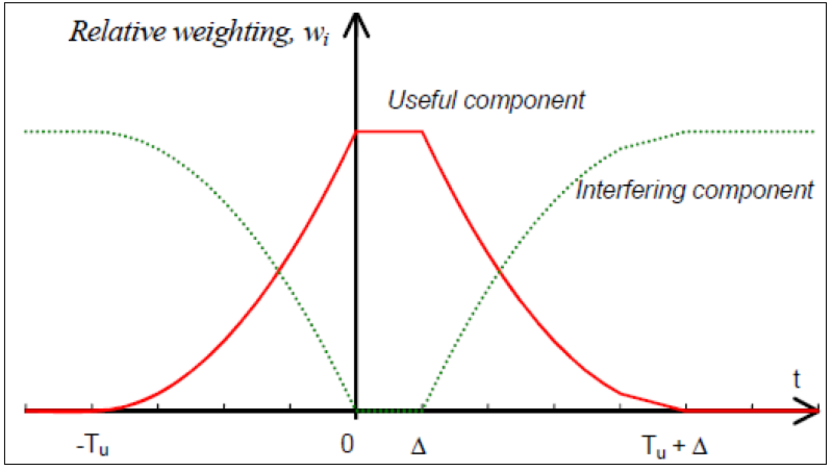
SFN timing constraints

The DAB signal is designed to allow SFN operation over a distance of 73.8 km

- Guard Interval Δ for Mode 1 = 246 μS
  - SFN distance limit = c Δ = 73.8 km
- Performance impact of out of GI
  - See EBU Tech 3391





Required protection ratio ζ	Relative delay
0 (i.e. not required)	0 ≤ t ≤ 246 μs (i.e. inside the guard interval)
5 dB	246 < t ≤ 350 μs
13.5 dB	t > 350 μs

Protection ratio for out of GI transmission components

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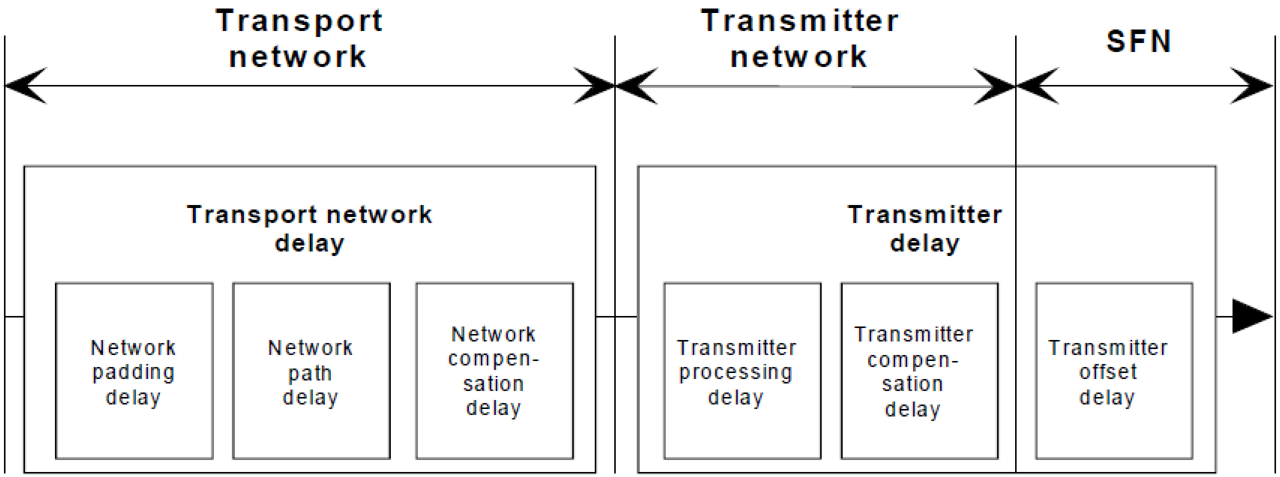
Timing model

The standard terminology for the delays in the systems are shown below

NOTE that transmitter manufacturers sometimes use their own terminology

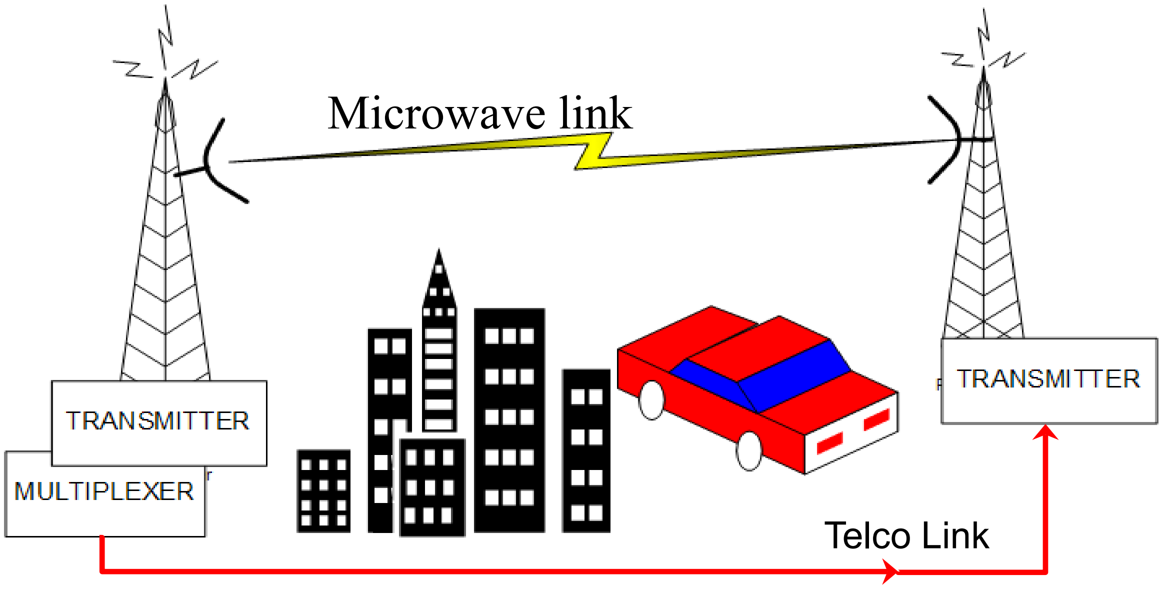


See ETSI ETS 300 799 – annex F

Repeater types – link fed

Link Fed Repeater

The repeater is fed by an EDI / ETI signal via a link
- Microwave
- Telco landline (fibre, dedicated or shared, diversity)



Repeater types – on-channel

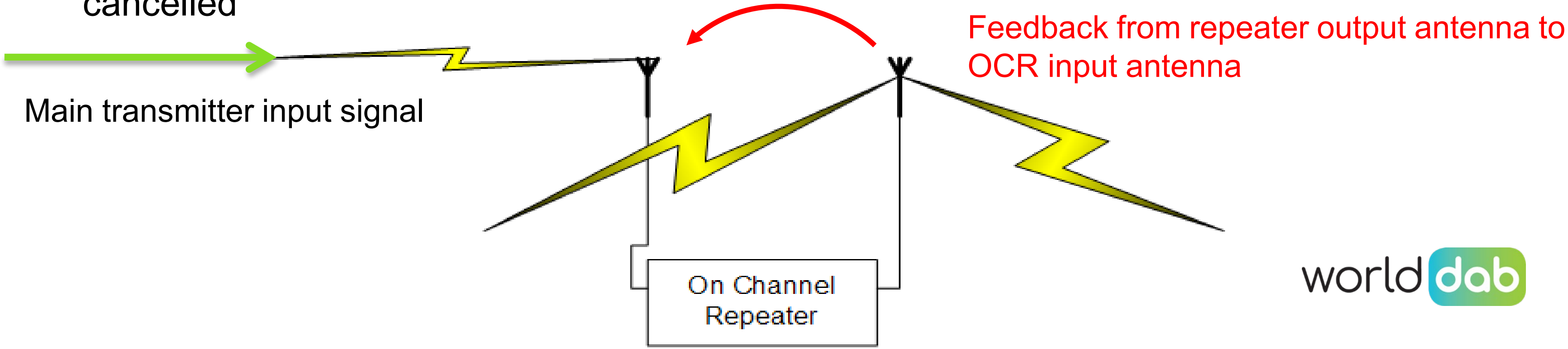
On Channel Repeater

Receives the signal off-air and then retransmits on the same frequency

Echo cancelling techniques allow repeaters which can re-transmit on the **same frequency**

The maximum power of the OCR is dependent on

- the input signal power after Rx antenna gain
- The Tx antenna to Rx antenna coupling ratio – Rx and Tx nulls provide most attenuation
- The accuracy of the echo cancelling system – typically 10dB of local signal can be cancelled



Examples - OCR

OCRs are low power e.g. <1 kW

Only issues if

- field strength difference is < CCI PR (12dB)
- time of arrival difference (ToA) is > GI (246 uS)

$$ToA\ difference\ = ABS(\ [OCR\ time\ delay] - Main\ time\ delay)\ \mu S$$

$$ToA\ difference\ = ABS\left(\ \left[\frac{distance\ Main\ to\ OCR}{c} + OCR\ processing\ delay + \frac{distance\ OCR\ to\ Rx}{c}\right] - \frac{distance\ Main\ to\ Rx}{c}\right)\ \mu S$$

CCI issues only possible if the OCR is > 34 km from the main Tx

The example model uses Egli's Rayleigh channel model for field strength prediction with exponent 3.8

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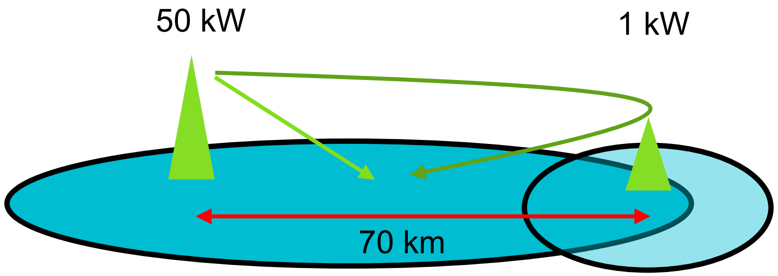
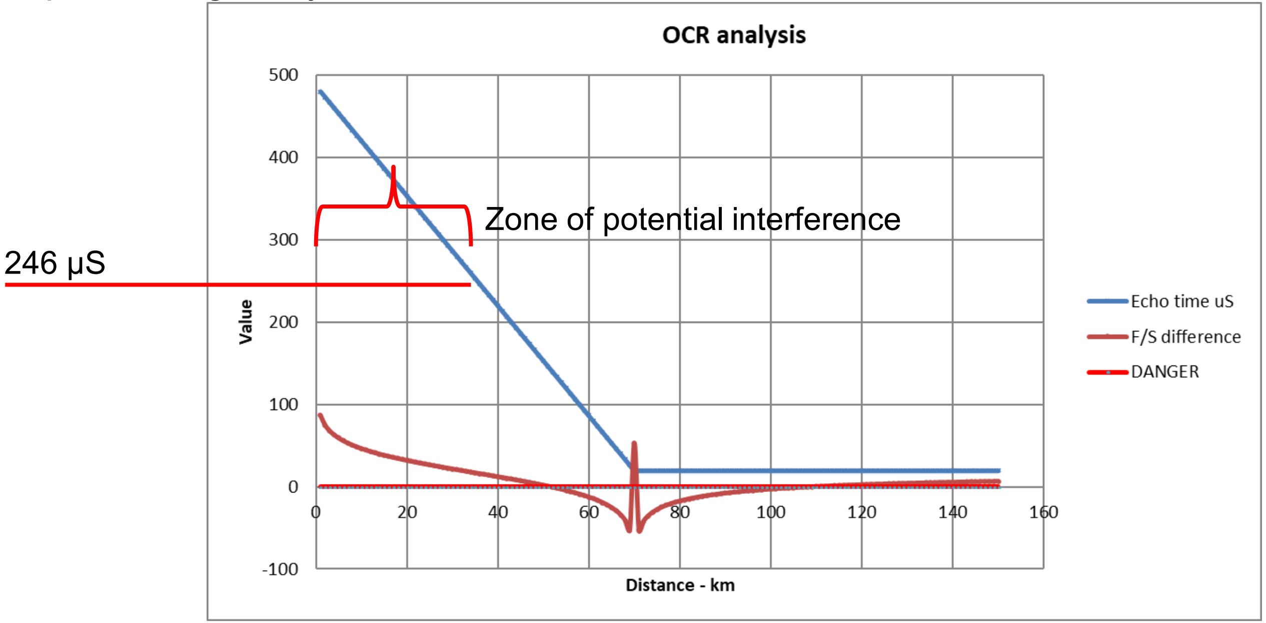
Examples - OCR

Edge of coverage extension

The time delay of the OCR signal must take into account the time required to travel to the OCR site and the OCR processing delay





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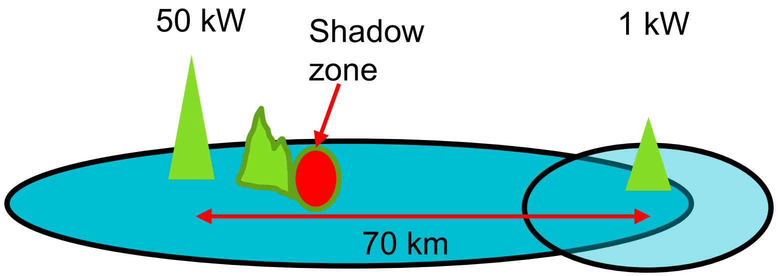
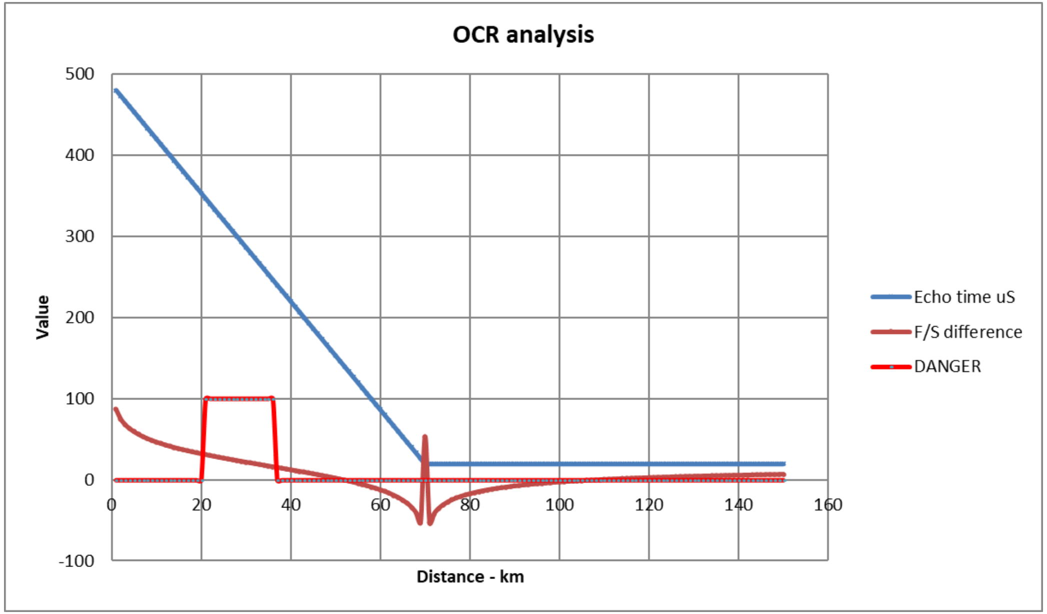
Examples - OCR

Edge of coverage extension



Impact of shadowing of main signal by high object

Shadow loss of 20 dB causes main signal to weaken below the CCI PR limit = coverage hole



OCRs are useful but care is needed to ensure no unexpected holes in coverage

Examples LFR

LFRs can be various powers from small infill at 1 kW to full main power

Only potential issues if the transmitter site spacing is >73.8 km

Issues only usually occur in shadowed areas

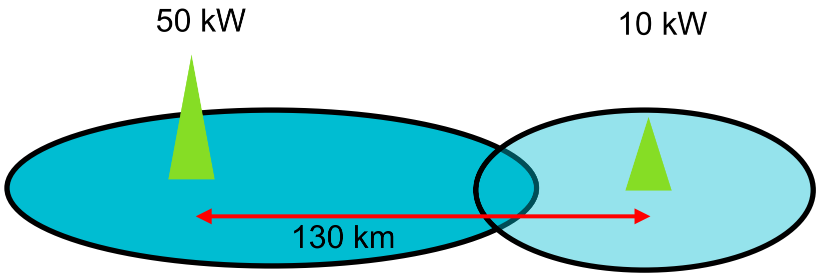
$$ToA\ difference\ = ABS(\,[LFR\ time\ delay] - Main\ time\ delay)\ \mu S$$

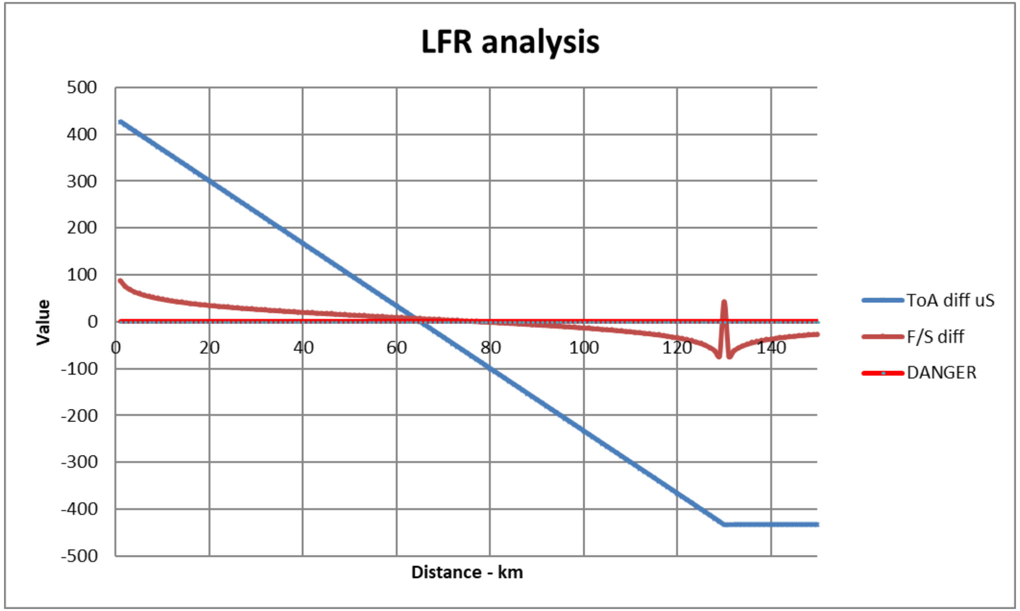
$$ToA\ difference\ = ABS\left(\left[\frac{distance\ LFR\ to\ Rx}{c}\right] - \frac{distance\ Main\ to\ Rx}{c}\right)\ \mu S$$

Examples - LFR

Wide area coverage

No shadowing





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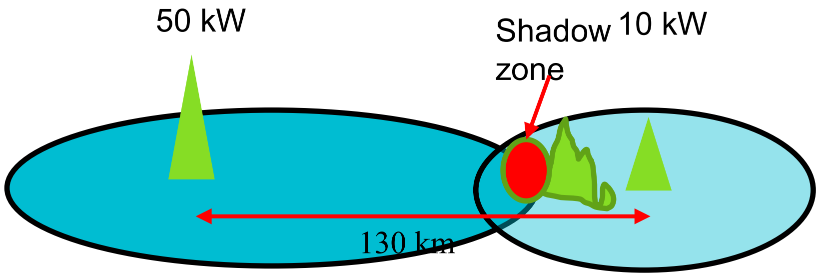
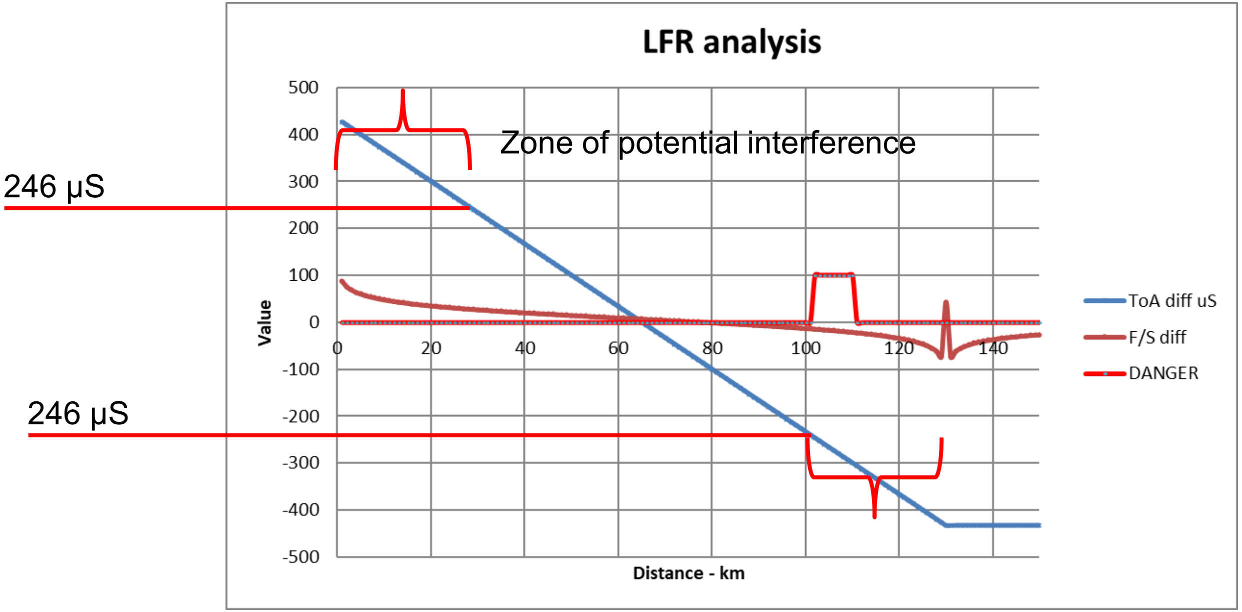
Examples - LFR

Wide area coverage

With shadowing loss (10dB)

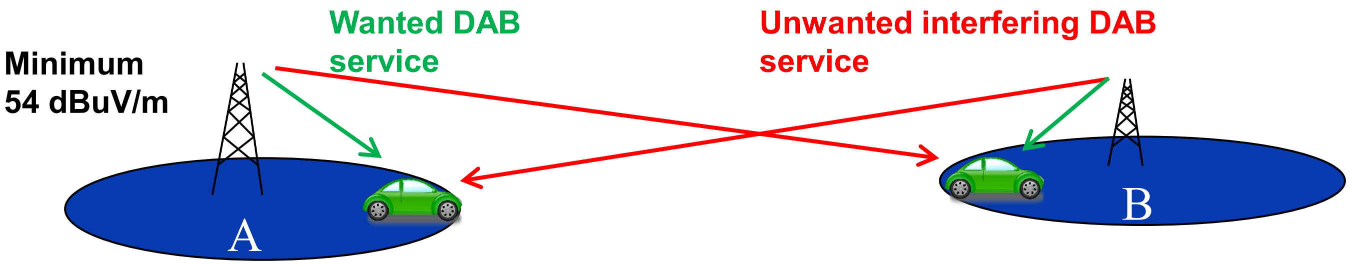




Planning and interference

Co-Channel Interference

The Co-Channel Interference allowance defines the minimum distance between different transmissions on the same frequency block



What is the maximum allowable interference field strength?

The maximum interfering field strength is defined relative to the wanted field strength

- the Co-Channel Protection Ratio typically 12 dB.

Terrain between co-channelled areas strongly influences the level of interference

Planning and interference

Allotment planning

- Determines the frequency blocks to be used in each area with individual content
- The CCI between areas using the same frequency block is usually required to be less than a specific measurement value, e.g. less than 2% of the interfered areas population

Cross border planning and coordination

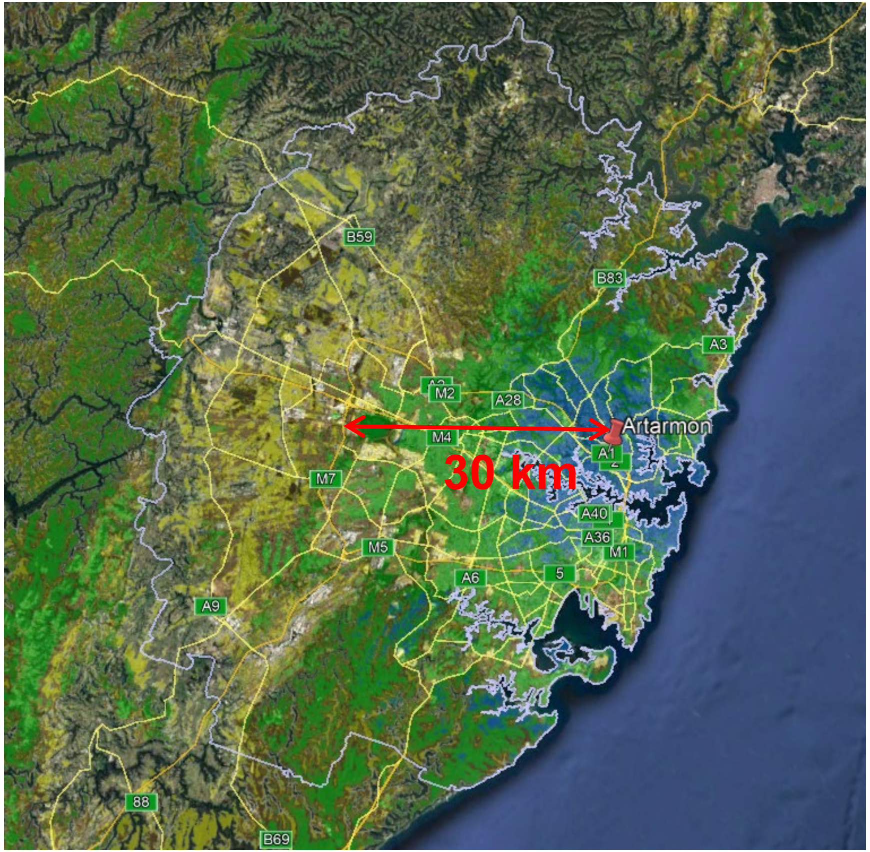
- usually done using the ITU P.1546 propagation model
- includes all users of VHF Band III – DAB and DTT

Case Study

Sydney, Australia

Single 45 kW main transmission

Areas more than approx. 30 km west of the main transmitter only receive vehicle grade coverage



Field strength pallete

- > 80 dBµV/m – dense urban indoor
- > 60 dBµV/m – urban indoor
- > 54 dBµV/m – suburban indoor
- > 50 dBµV/m – vehicle

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Case Study

Sydney, Australia

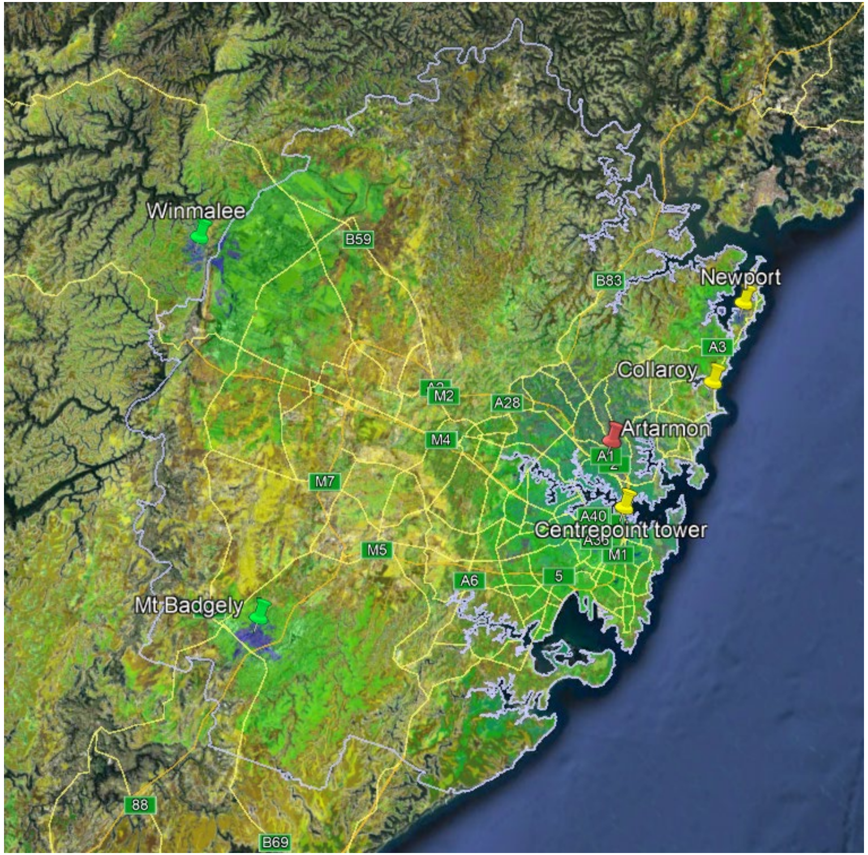
5 repeaters

2 x LFR @ 500W

3 x OCR @ 300W

Largely cover the populated areas with at least suburban grade coverage

Further urban expansion in Western Sydney will require further repeater support for indoor coverage



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Case study

Sydney northern beaches - Terrain shielding and undulations

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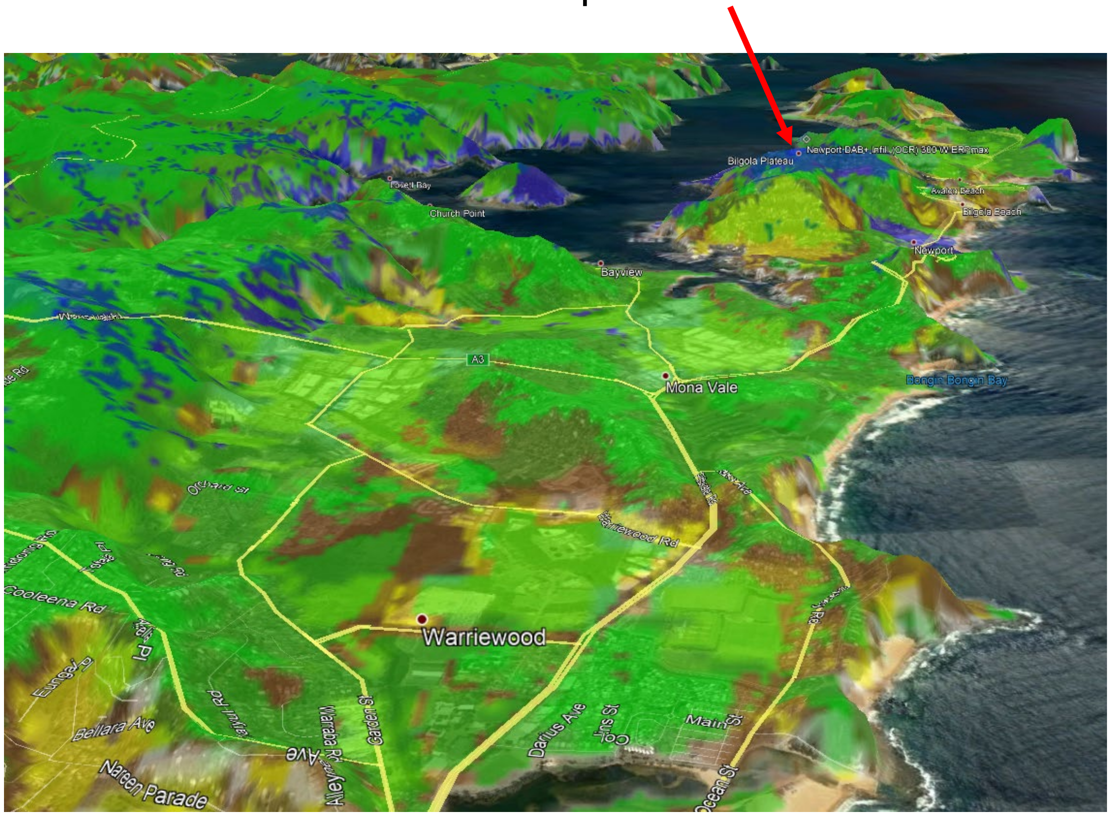
Case study

With 300W repeater



Case study

City building shielding - Melbourne

Mt Dandenong transmitter 45kms

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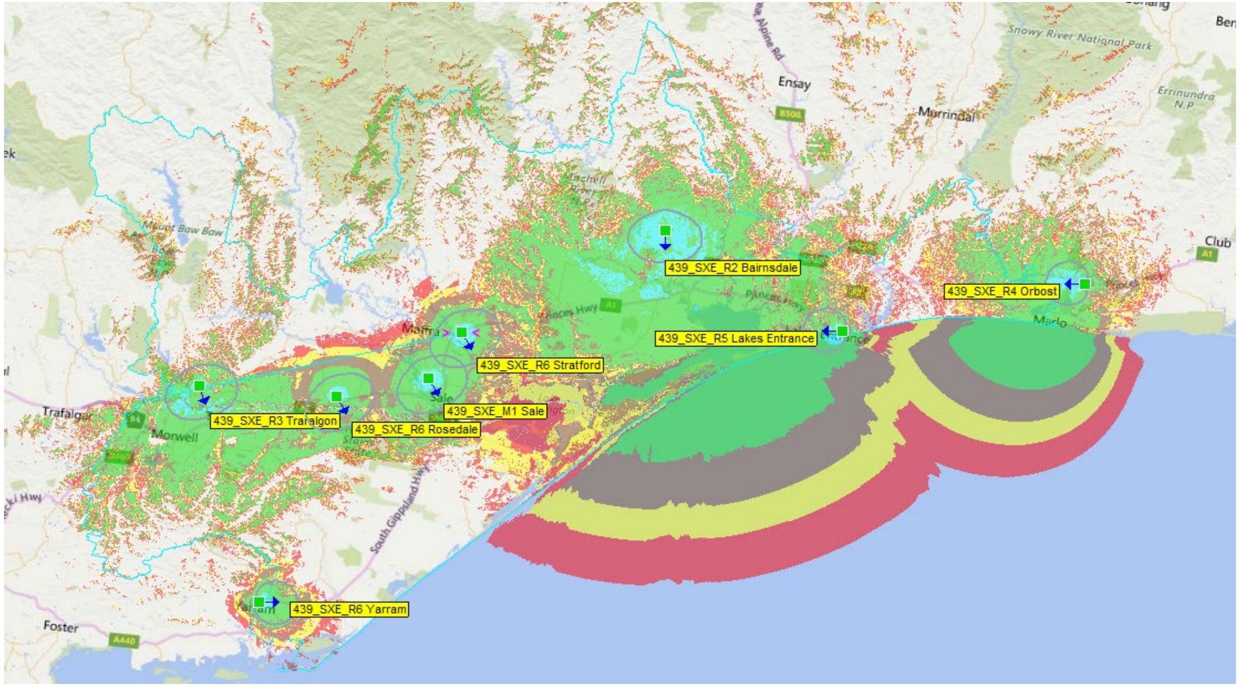
Case study

SFN coverage in Sale, Victoria, Australia

7 transmitters to cover 200km ranging from 1 to 5kW each



Conclusions

1. Coverage requirements come first BUT may need to be adjusted depending on the demand for and availability of spectrum
2. Full coverage can be provided BUT there will always be a trade-off between % coverage and COST
3. The last few % of population coverage can be very expensive – needs to be realistic
4. Generally better to plan the overall national network allotments and then rollout the infrastructure in phases
5. Always use SFNs to advantage to maximise spectral efficiency
6. Use modern coverage planning and interference analysis tools to maximise accuracy – good planning can save SIGNIFICANT cost
7. Plan ahead within an overall programme of activities to establish DAB+

Thank you

For further information, please contact:

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