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Link Budgets

Update 02/2009

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February 2009

This **bmco**forum white paper has been edited by the members of the "Network structure and coverage expectations" work item.

Content:

1. Introduction

For the planning of radio networks, a traditional approach consists in defining the required minimum median field strength that must be offered in a target area and then predict the locations where this level can be reached, using planning tools.

This document intends to list, for the various usage scenarios, what standard field strength values should be used for network planning of DVB-T, DVB-H, T-DMB, MediaFLO and DVB- SH[1] services. In addition, it also provides the corresponding required minimum terminal sensitivity in each usage scenario.

This document is an update of **bmco**forum white paper on link budgets, first published in 2007. This second version is based on the latest additional performance test results available for the most prominent Mobile Broadcast Technologies in Europe. It also gives practical reference terminal sensitivity figures, and numerous technical clarifications.

[1] DVB-SH (DVB-Satellite Services to Handhelds) was formerly named DVB-SSP (Satellite Services to Portables).

2. Usage scenarios

Whatever the technology, four use cases are considered, in line with definitions from [1], [3]:

Class A: Outdoor reception where the portable terminal with an attached or built-in antenna is used. Reception is considered at 1.5 m above ground level, at a speed of 3km/h.

Class B: Indoor reception where the portable terminal with an attached or built-in antenna is used. The terminal is at 1.5 m above floor level on the ground floor, in a room with a window in an external wall.

Because field experiments have produced varied estimates of the impact of building penetration, two sub-categories for class B are further defined:

> **Class B1:** Light-indoor reception, for a portable terminal close to a window in a lightly shielded room.
>
> **Class B2:** Deep-indoor reception, for a portable terminal located further away from a window, in a highly shielded room.

Class C: Mobile reception where the terminal is located in a moving vehicle and receives the signal from an external, outdoor antenna. Reception is considered at 1.5m[2] above ground level at a speed of up to 130km/h.

Class D: Mobile reception where the terminal is located in a moving vehicle and receives the signal from an attached or built-in antenna. Reception is considered at 1.5m above ground level at a speed of up to 130km/h.

Class of Reception	Situation	Characteristics
Class C	Mobile roof-top	1.5m above ground level, up to 130km/h
Class A	Outdoor pedestrian	1.5m above ground level, 3km/h
Class D	Mobile in-car	1.5m above ground level, up to 130km/h
Class B1	Light-indoor	1.5m above ground floor level, 3km/h, lightly shielded building
Class B2	Deep-indoor	1.5m above ground floor level, 3km/h, highly shielded building

Table 1: Classes of reception, by expected order of increasing difficulty of reception

2 1.5 m height is a worst case value, but realistic in several countries.

3. Link Budget Evaluation

The minimum median equivalent field strength required outdoor at 1.5 m above ground level is given by formula (4) in the following paragraphs. This formula is obtained by evaluating the link budget in a three-step process, as illustrated in Figure 1:

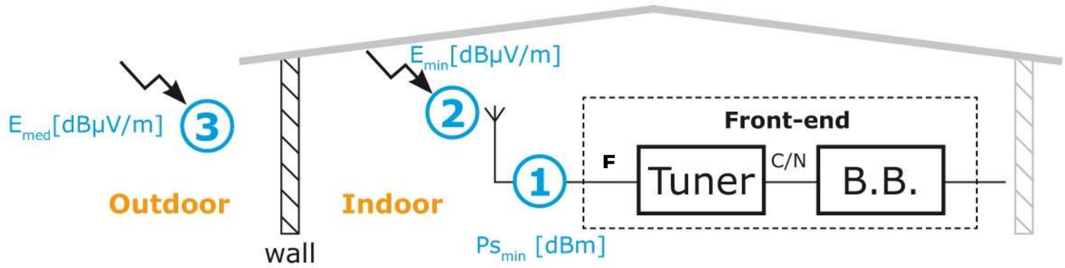

Figure 1: Reference Model for Link Budget evaluation

1) The *required minimum received power level* (**Ps_{min}**) is calculated at the front-end tuner input (in dBm).
2) The *required field strength* (**Emin**) near the receiving antenna is calculated, for a given antenna gain (in dBµV/m).
3) Finally, the *minimum median equivalent field strength* (**Emed**) required outdoor is calculated, including margins for indoor or outdoor coverage with the wanted percentage of covered locations.

<u>Step1</u>: minimum required RF power level at the receiver input ($P_{S min}$)

The minimum required RF input power level (PS_{min}) is related to the Carrier-to-Noise Ratio (C/N), the receiver Noise Figure (F) and the spectrum Bandwidth (B) by using the following formula:

$$\frac{C}{N} = \frac{P_{S\min}}{Pn} = \frac{P_{S\min}}{FkT_0B}$$

Where:

Pn = Receiver Noise input Power {W} [or {dBW} / {dBm}]
F=Receiver Noise Figure [$10\log_{10}$(F) in {dB}]
P_{Smin} = Minimum receiver input power {W} [or {dBW} / {dBm}]
k = Boltzmann's Constant (k= 1.38 x 10^{-23} {Ws/K})
T_0 = Absolute temperature (T_0 = 290° {K})
B = Receiver noise bandwidth {Hz}

Taking logarithm of both sides of previous formula and expressing B in MHz gives PS_{min}:

$$P_{S\min\{dBm\}} = \left(\frac{C}{N}\right)_{\{dB\}} + F_{\{dB\}} - 114 + 10\log_{10}\left(B_{\{MHz\}}\right) \quad (1)$$

Step2: ***Minimum required field strength at the antenna input (Emin)***

The input RF power level Ps_{min} (Watt or dBm) is practical in laboratory conditions, but in the field or in an anechoic chamber – i.e. using using a complete terminal including the antenna – the field strength (dBµV/m) is needed instead. Assuming a receiving antenna gain (G) and a working frequency (f), the required field strength (Emin) is calculated versus the minimum RF input power level (PS_{min}) by using the following formulas:

$Ps_{min} = Aa \times \Phi_{min}$

- Aa = *Effective antenna aperture {m²} (or {dBm²})*
- Φ_{min} = *Minimum power flux density at receiving place {W/m²} or {dBW/m²}*

with $\Phi_{min} = \frac{(E\min)^2}{Z}$

- E_{min}= *Equivalent minimum field strength near the antenna {V/m} or {dBmV/m}*
- Z = *Free space wave impedance* $= \sqrt{\frac{\mu_0}{\varepsilon_0}} = 120\pi$ {Ohms}

and $Aa = G \times \frac{\lambda^2}{4\pi}$

- λ= *Wavelength of the signal {m}*
- λ= *c/f with c= Light speed {m/s}*
  f= Carrier Frequency {Hz}
- G = *Antenna Gain compared to isotropic antenna {dBi}*

And finally, a combination of the three previous formulas gives Emin, the equivalent minimum field strength which has to be measured near the antenna to ensure a good reception:

$$E_{\min} = 4\pi \frac{f}{c}\sqrt{30\frac{P_{S\min}}{G}}$$

Or, expressing the parameters in decibels:

$$E\min_{\{dBV/m\}} = P_{S\min\{dBW\}} - G_{\{dBi\}} + 20\log_{10}\left(f_{\{MHz\}}\right) - 132.8$$

Using the following conversion formulas:

$$E_{\min\{dB\mu V/m\}} = E_{\{dBV/m\}} + 120$$

$$P_{S\{dBm\}} = P_{S\{dBW\}} + 30$$

equation (2) gives Emin with a more convenient unit of measurement:

(2) $$\boxed{E\min_{\{dB\mu V/m\}} = P_{S\min\{dBm\}} - G_{\{dBi\}} + 20\log_{10}\left(f_{\{MHz\}}\right) + 77.2}$$ ([7] §10.1)

*__Note:__ The_**T**otal **R**adiated **S**ensitivity (TRS) as defined in 3GPP to characterize receiver together with antenna [9] may be used instead of antenna gain and receiver sensitivity. TRS measurement is on the way to be specified within the framework of MBRAI / EICTA in IEC 62002-4. Whenever using TRS, formula (2) becomes:*

(2bis) $$\boxed{E\min_{\{dB\mu V/m\}} = TRS_{\{dBm\}} + 20\log_{10}\left(f_{\{MHz\}}\right) + 77.2}$$

Step3: ***Minimum median equivalent field strength* outdoor with coverage margin (Emed)**

Macro-scale variations of the field strength are very important for the coverage assessment (see section 4.3).

- For **outdoor** reception, only the outdoor environment causes signal variations.
- For **indoor** signals, the given variation corresponds to the cumulative effects of outdoor and indoor or in-vehicle environments. As outdoor and indoor macro-scale variations of the field strength were found to follow a "log Normal" law, the combined standard deviation (σ) is given by:

$$\sigma = \sqrt{(\sigma_o)^2 + (\sigma_p)^2}$$

where σ_p is the standard deviation of the indoor penetration loss (see section 4.2)

Macro-scale variations of the field strength shall be multiplied by a correction coefficient *μ*, according to the target Quality of Coverage defined by the wanted percentage of covered locations. A widely used model assumes that the received mean power of the radio signal fluctuates around the mean power received on a "small" area, according to a log-normal distribution (Figure 2): for example, Emin corresponds to 50% reception probability, while adding $1.64 \times \sigma$ is needed to reach 95% reception probability. The values corresponding to a "good" and "acceptable" quality of coverage for mobile TV are given in section 4.1.

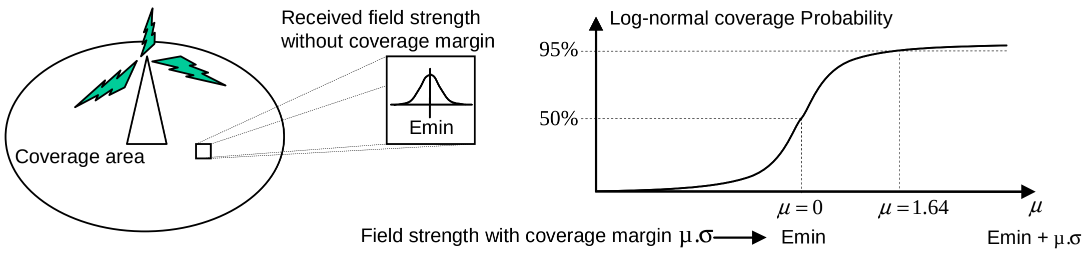

Figure 2: Derivation of correction factor *μ* from wanted coverage probability

Finally Emed, the minimum median electric field strength, assuming a given Quality of Coverage, can be calculated as follows:

(3) $$Emed_{\{dB\mu V/m\}} = E\min_{\{dB\mu V/m\}} + L0 + Lp + \mu \times \sigma$$

Where

σ Combined standard deviation {dB}
μ Correction coefficient
Lp Building and vehicle penetration losses {dB}
L0 All other losses (man-made noise, polarization mismatch, cable losses, miscellaneous) {dB}

Finally, combination of the formulas (1), (2) and (3) gives:

(4)
$$Emed_{\{dB\mu V/m\}} = \left(\frac{C}{N}\right)_{\{dB\}} + F_{\{dB\}} - G_{\{dBi\}} + 10\log_{10}\left(B_{\{MHz\}}\right) + 20\log_{10}\left(f_{\{MHz\}}\right) - 36.8 + L0_{\{dB\}} + Lp_{\{dB\}} + \mu\sigma_{\{dB\}}$$

When using TRS instead of antenna gain and PSmin, the formula simplifies to:

(4bis)
$$Emed_{\{dB\mu V/m\}} = TRS_{\{dBm\}} + 20\log_{10}\left(f_{\{MHz\}}\right) + 77.2 + L0_{\{dB\}} + Lp_{\{dB\}} + \mu\sigma_{\{dB\}}$$

4. Technology independent parameters

4.1. Quality of Coverage

For a given small area of 100mx100m, the quality of coverage is classified as:

- "Good",
  - if at least 95 % of receiving locations at the edge of the area are covered for portable reception (Class A,B);
  - if at least 99 % of receiving locations within it are covered for mobile reception (Class C, D)[3];
- "Acceptable",
  - if at least 70 % of locations at the edge of the area are covered for portable reception (Class A,B);
  - if at least 90 % of receiving locations within it are covered for mobile reception (Class C, D)[3];

The correction coefficient can then be derived, assuming a normal distribution of field strengths.

Quality of Coverage	**Class A,B**	**Class C,D**
Good	95%, μ=1.64	99%, μ=2.33
Acceptable	70%, μ=0.52	90%, μ=1.28

Table 2: Quality of coverage and corresponding correction coefficient μ.

4.2. Penetration losses

For class B and D, additional building and vehicle penetration losses must be taken into account.

In class B, the average value of the building penetration loss is the difference between the average value of the outdoor signal level distribution and the average value of the indoor signal level distribution at the same height.

$$Lp = Eout_{average} - Ein_{average}$$

[3] 99% and 90% coverage of the area respectively correspond to approximately 95% and 70% edge coverage of the area, see Annex .

Band	VHF[4]		UHF[5]		L-band[4]		S-band[6]	
Penetration loss Lp	**Loss**	**Stand. Dev.**	**Loss**	**Stand. Dev.**	**Loss[7]**	**Stand. Dev.**	**Loss**	**Stand. Dev.**
Class C	none	none	none	none	none	none	none	none
Class A	none	none	none	none	none	none	none	none
Class D	7 dB	none	7 dB	none	7 dB	none	7 dB	none
Class B1	9 dB	σ_p=4.5 dB	11 dB	σ_p=5 dB	13 dB	σ_p=5 dB	14 dB	σ_p= 5 dB
Class B2	15 dB	σ_p=5 dB	17 dB	σ_p=6 dB	19 dB	σ_p=6 dB	19 dB	σ_p= 6 dB

Table 3: Penetration losses

4.3. Combined Field strength variation

Macro-scale variations of the field strength are very important for the coverage assessment. For outdoor signals, the standard value of σ_o=5.5dB (from [2]) is used.

In case of class B and D, the given variation corresponds to the cumulative of the outdoor signal variation and the indoor or in-vehicle variation, as listed in the previous section.

Since

$$\sigma = (\sigma_o^2 + \sigma_p^2)^{1/2}$$

the following values for the combined field strength variation are thus derived:

Combined Field Strength Variation σ	**VHF**	**UHF**	**L-Band**	**S-Band**
Class C	σ=5.5 dB	σ=5.5 dB	σ=5.5 dB	σ=5.5 dB
Class A	σ=5.5 dB	σ=5.5 dB	σ=5.5 dB	σ=5.5 dB
Class D	σ=5.5 dB	σ=5.5 dB	σ=5.5 dB	σ=5.5 dB
Class B1	σ=7.1 dB	σ=7.4 dB	σ=7.4 dB	σ=7.4 dB
Class B2	σ=7.4 dB	σ=8.1 dB	σ=8.1 dB	σ=8.1 dB

Table 4: Field strength variation

[4] From T-DMB trials in Australia (T-Systems). These figures are also in line with document "*CRA / DRBA T-DAB Sydney Trial – Building penetration loss Survey Band III and L-Band*", 12 oct 2005.

[5] From DVB-H trials in Finland and France

[6] These values are extrapolated from L-band in order to have consistent penetration losses figures across the entire frequency range. State of the art practice in UMTS network planning from Alcatel-Lucent differs slightly: 10-12 dB / 18-21 dB penetration losses for respectively light/deep indoor, and respectively 8/10 dB combined field strength variation (in Table 4).

[7] L-Band penetration losses match a linear extrapolation from VHF and UHF

4.4. Antenna gain

The antenna gain below is defined as the maximum gain on the antenna pattern. The achievable antenna gain can be characterised as follows:

Frequency (MHz)	Class A,B,D with built-in antenna	Class A,B,D with attached antenna	Class C
VHF Band III (225)	-16 dBi[8]	-12 dBi[9, 10]	-3 dBi[11]
UHF (474)	-10 dBi[12]	-6 dBi[9]	0 dBi[11]
UHF (698)	-7 dBi[12]	-3 dBi[9]	0 dBi[11]
UHF (858)	-5 dBi[12]	-1 dBi[9]	1 dBi[11]
L-Band	-5 dBi / 0 dBi[13]	-3 dBi / 0 dBi[13]	0 dBi [13]
S-Band (2170)	-3 dBi[14]	0 dBi[14]	+2 dBi[14]

Table 5: Antenna gain

In the following link budget calculations, built-in antennas are considered for classes A, B, D.

4.5. Other losses

Other losses must be considered in the link budget. To take all other possible losses into account, an additional loss has to be included in the link budget.

This shall account for:

- Practical antenna gain with respect to maximum gain (depending on antenna pattern, possible polarisation mismatch, …),
- Implementation losses (front-end performances),
- Cable loss in the case of car roof-top antenna (class C),
- Man-made noise.

[8] From measurements at IRT.

[9] +4 dBi with respect to an integrated antenna. This relative value originates from EBU B/BCP group and document EBU Tech 3317 *(Planning parameters for hand-held reception v2, july 2007)*

[10] Applies to a handheld terminal, i.e. with limited length antenna extension. Bigger portable terminals have a better antenna gain (e.g. -6 dBi for 75 cm reported in Digital Radio Australia "*Planning F/S and derivation T-DAB reception for mobile and indoor"* report, *29th jan 2008*)

[11] From EICTA MBRAI interface specifications v2.0, June 2007

[12] From DVB-H Implementation Guidelines ETSI TR 102 377 V1.2.1 (2005-11)

[13] -5 dBi: currently used for planning, referred to 1 dBi in ETSI TR 101 758 V2.1.1 (2000-11)

[14] From DVB-SH Implementation Guidelines ETSI TS 102 584 V1.1.1, sections 10.1.2.2 and 4.2.6.2

There are many possible loss values for each individual item above, depending on usage scenario and technology. Considering that it is unlikely that all effects would occur simultaneously, a global value in the order of 3 dB to 5 dB used for all classes.

	DVB-H in UHF	**MediaFLO in UHF**	**T-DMB in VHF and L-Band**	**DVB-SH in S-Band**[15]
Loss	3 dB	3 dB	5 dB	1 dB

Table 6: "Other losses" values

[15] To be confirmed based on future lab and field tests using the first integrated handheld terminals. "Other losses" for S band is estimated at 1 dB since: the section 4.4 already considers a practical antenna gain, no cable loss is foreseen with low noise amplifier at antenna in case of roof top configuration, the noise figure performance of section 6.2 already takes into account front-end implementation loss and finally man made noise is negligible in S band.

5. Network architecture dependent factors

The factors in this section are highly dependent on specific network architecture and equipment implementations. For this reason they are not included in the link budget calculation.

5.1. SFN gain

The "SFN gain" (Single Frequency Network) is the reduction of number of transmitters to cover a given area using synchronised transmitters compared to the number of independent MFN transmitters. Depending on the network topology, this transmitter savings may be carefully translated into an average increase of coverage.

However, the SFN gain is not persistent across all points of the network, so it will not be considered in the link budget.

5.2. Antenna diversity gain

Antenna diversity accounts for the possibility for a receiver to use several receive antennas to exploit multi-path propagation.

In general, this feature may not be implemented on all devices, so it will not be considered in the link budget.

In the case of DVB-SH, it is foreseen that antenna diversity will be used, with the expected diversity gains:

DVB-SH	**Reception diversity gain**
C – Mobile roof-top[16]	2.5 dB / 4.0 dB[17]
A – outdoor	2.5 dB / 4.0 dB
D – Mobile in-car	> 2.5 dB
B1 – Light indoor[16]	6 dB
B2 – Deep indoor	6 dB

Table 7: Measured antenna diversity gain in DVB-SH terminal[18]

[16] From field trials performed by Alcatel in Pau in 2008

[17] Alcatel field trials show an average diversity gain in outdoor of 2.5 dB in rural environment and 4.0 dB in urban environment

[18] Measured with experimental receivers. To be confirmed using the first integrated handheld terminals.

6. Technology dependent parameters

6.1. Bandwidth

Receiver bandwidths to be considered in link budget calculations are listed below:

Channel (MHz)	1.7	5	6	7	8
DVB-T¸DVB-H (MHz)	-	4.75	5.71	6.66	7.61
MediaFLO (MHz)	-	4.52	5.42	6.32	7.23
T-DMB (MHz)	1.54	-	-	-	-
DVB-SH (MHz)	1.52	4.75[19]	5.71	6.66	7.61

Table 8: Signal bandwidth

6.2. Noise Figure

The receiver noise figure essentially depends on frequency, and on the bandwidth each technology is designed for. The terminal noise figure also depends on the terminal design regarding the integration of receiver chip.

For example, an additional LNA (Low Noise Amplifier) might be present before the receiver chip (Figure 3), depending on terminal requirements on sensitivity, input dynamics, and adjacent channel interference.

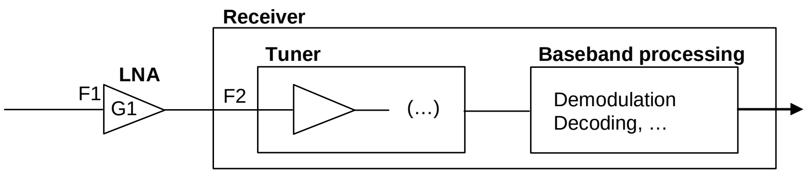

Figure 3: Schematic view of a receiver architecture including an additional LNA in front of the tuner

Using such an architecture, the resulting noise figure is given by:

$$F = F1 + (F2 - 1)/G1$$ (in linear scale)

[19] In S-band 5 MHz will most likely be used.

The following noise figure values take into account GSM rejection unless otherwise noted:

	Noise figure for planning
T-DMB (VHF 225MHz)	6 dB[20]
DVB-T¸DVB-H (UHF 470-750MHz)	4 dB[21] / 6 dB[22]
MediaFLO (UHF)	6 dB[23]
T-DMB (L-band)	3.5 dB / 7 dB[20]
DVB-SH (S-band 2170-2200MHz)	4.5 dB / 6.0 dB[24]

Table 9: Noise figures to be considered for network planning

6.3. Carrier-to-Noise ratio

The carrier-to-noise ration (C/N) is a characteristic determined by the type of modulation. Regarding the receiver implementation, the C/N is only determined by the quality of the baseband processing in the demodulator.

It is considered that the following C/N ratios should be used as basis for computation of link budgets:

6.3.1. DVB-T

Assumptions:

- Laboratory and field experiments; real receiver implementations [7]
- Bandwidth: 8 MHz in UHF band
- Quality criterion : ESR 5%
- Channel model: TU6 for classes C,D. For classes A and B, PO and PI models are used respectively

[20] From ETSI TR 101 758 V2.1.1 (2000-11). 7dB in L-Band is currently used in planning by T-Systems / MFD .

[21] For handheld receiver without GSM rejection filter. From EICTA MBRAI interface specifications v2.0, June 2007

[22] From EICTA MBRAI interface specifications v2.0, June 2007

[23] FLO Minimum Performance Specification [5] defines the receiver noise figure level at 9.5 dB. However, this figure may vary depending on actual implementation requirements, which is typically between 6 and 8 dB.

[24] Measured values by Alcatel show a Noise Figure of 4.5 dB with a LNA and 6.0 dB without LNA. Confirmed by Alcatel measurements done on DVB-SH in S-band handset prototypes.

	QPSK 1/2	16QAM 2/3	64QAM 2/3
Class A	10.5 dB	19.5 dB	24.3 dB
Class B	9 dB	18 dB	22.8 dB
Class C,D	15 dB	23 dB	29 dB
Max receiver speed at 698 MHz (doppler shift)	*90 km/h (60 Hz)*	*90 km/h (60 Hz)*	*55 km/h (35 Hz)*
Net datarate (8 MHz)[25]	*5.53 Mbit/s*	*14.74 Mbit/s*	*22.11 Mbit/s*
Net datarate (8 MHz)[26]	*6.03 Mbit/s*	*16.08 Mbit/s*	*24.12 Mbit/s*

Table 10: Minimum required C/N for DVB-T receivers

6.3.2. DVB-H

Assumptions:

- Laboratory and field experiments; real receiver implementations [1] [7], including implementation losses
- Bandwidth: 8 MHz in UHF band
- Quality criterion : MPE FER 5%
- Channel model: TU6 for classes C,D, PO for class A, PI for class B
- Max receiver speed: 5 km/h (Class A, B) and about 160 km/h / 100 Hz Doppler shift (Class C, D) at 698 MHz.

	QPSK ½ MPE FEC 3/4	QPSK 2/3 MPE FEC 3/4	16QAM ½ MPE FEC 3/4	16QAM 2/3 MPE FEC 3/4
Class A	7 dB	10 dB	13 dB	16 dB
Class B	8 dB	11 dB	14 dB	17 dB
Class C,D	8.5 dB	11.5 dB	14.5 dB	17.5 dB
Net datarate (8 MHz)[27]	*3.74 Mbit/s*	*4.98 Mbit/s*	*7.46 Mbit/s*	*9.95 Mbit/s*
Net datarate (8 MHz)[28]	*4.15 Mbit/s*	*5.53 Mbit/s*	*8.30 Mbit/s*	*11.06 Mbit/s*

Table 11: Minimum required C/N for DVB-H receivers

[25] For Guard Interval 1/8
[26] For Guard Interval 1/32
[27] For Guard Interval 1/4
[28] For Guard Interval 1/8

6.3.3. MediaFLO

Assumptions:

- Derived from field trial measurements
- C/N data provided by receiver
- Bandwidth: 8 MHz
- Quality criterion : 1% PER (after Reed-Solomon decoding)
- C/N for class A,B is the average value of measured C/N at speeds between 0 and 6 km/h, at 719 MHz.
  C/N for class C,D is the average value of measured C/N at speeds between 90 and 110 km/h, at 719 MHz.
- Max receiver speed : 6 km/h (Class A, B) and 110 km/h (Class C, D)

	Mode 1 QPSK ½	**Mode 2 16QAM 1/3**	**Mode 7 QPSK ½ Base**	**Mode 7 QPSK ½ Enhanced**
Class A,B	6 dB[4]	8 dB[4]	9 dB[4]	13.5 dB[4]
Class C,D	7 dB[4]	9 dB[4]	10 dB[4]	14.5 dB[4]
Net datarate (8 MHz)	*4.2 Mbit/s*	*5.6 Mbit/s*	*8.4 Mbit/s*	*8.4 Mbit/s*

Table 12: Minimum required C/N for MediaFLO receivers

Alternative C/N targets and associated data rates based on two transmitters in SFN, using Ped B emulation channel [10] or field measurements up to 120km/h, as well as other FLO supported modes, can be found in [4].

6.3.4. T-DMB

Assumptions:

- Lab measurements from Media Broadcast (L-Band)
- Bandwidth: 1,7 MHz in VHF and L-Band
- Quality criterion : 5% ESR
- Channel model : TU6
- Max receiver speed : 270 Hz (Mode II Level 3A)

	Mode I/II Level 3A
Class A,B	12 dB
Class C,D	13 dB
Net data rate	*1.06 Mbit/s*

Table 13: Minimum required C/N for T-DMB receivers

C/N values for other Protection Levels are under study

6.3.5. DVB-SH

Assumptions:

- Lab measurements from CELTIC B21C project [8]
- Includes provisioning implementation margin for the demodulator
- Bandwidth: 5 MHz in S-Band (2170 MHz)
- Short Time Interleaving (i.e. terrestrial applications): 160 to 320 ms
- Quality criterion : FER 5%
- Channel model: TU6 in terrestrial propagation conditions
- Max receiver speed : 5 km/h (Class A, B) and about 160 km/h (Class C, D)

	QPSK 1/3 TC	**QPSK 1/2 TC**	**16QAM 1/3 TC**
Class A, B, C, D [29, 30]	3.0 dB	6.3 dB	9.1 dB
Net data rate (5 MHz)[31]	*2.22 Mbit/s*	*3.35 Mbit/s*	*4.44 Mbit/s*
Net data rate (5 MHz)[32]	*2.46 Mbit/s*	*3.73 Mbit/s*	*4,93 Mbit/s*

Table 14: Minimum required C/N for DVB-SH receivers

[29] From CELTIC B21C project measurements.
[30] In vehicular usage, the required C/N is about 1 dB lower at a specific speed (90 km/h in the above configurations)
[31] For Guard Interval 1/4
[32] For Guard Interval 1/8

6.4. Coverage classes

For network planning purposes, five reception categories are defined, considering that some combinations of usage scenarios and quality of coverage levels require similar typical field strength at 1.5m.

A BMCO coverage class is defined to cover the requirements of all usage scenarios and coverage quality levels that map to this class. For example, The required median field strength for a BMCO_I class is the highest field strength of "Acceptable outdoor pedestrian" and "Acceptable mobile roof-top" scenarios.

Table 15 lists BMCO coverage classes by order of increasing difficulty of reception (e.g. class BMCO_V also covers all other usage scenarios of lower classes).

BMCO_I	- Acceptable outdoor pedestrian - Acceptable mobile roof-top
BMCO_II	- Good mobile roof-top - Good outdoor pedestrian
BMCO_III	- Acceptable Light indoor - Acceptable mobile incar
BMCO_IV	- Good mobile in-car - Acceptable deep indoor - Good light indoor
BMCO_V	- Good deep indoor

Table 15: BMCO classes of coverage by expected order of increasing difficulty of reception

These categories map to usage scenarios and quality of coverage as described in the table below:

		Quality of Coverage:	
Usage scenario:		**Good**	**Acceptable**
Class A	Outdoor pedestrian	BMCO_II	BMCO_I
Class C	Mobile roof-top	BMCO_II	BMCO_I
Class D	Mobile in-car	BMCO_IV	BMCO_III
Class B1	Light-indoor	BMCO_IV	BMCO_III
Class B2	Deep-indoor	BMCO_V	BMCO_IV

Table 16: BMCO classes mapping to usage scenarios

7. Reference minimum field strengths for network planning

The minimum median equivalent field strength values are calculated as described in section 3 and rounded to the upper dB, for all BMCO coverage classes previously defined in section 6.4. **Terminals with built-in antenna (section 4.4) are assumed except for Mobile car roof-top reception. Network architecture dependent factors (section 5) are not taken into account**.

Note: The following minimum field strength values can be converted to minimum received power values in dBm using equation (2) in section 3, page 8:

7.1. DVB-T

DVB-T	QPSK 1/2	16QAM 2/3	64QAM 2/3
C – Mobile roof-top	67 dBµV/m	75 dBµV/m	81 dBµV/m
A – Outdoor	65 dBµV/m	74 dBµV/m	79 dBµV/m
D – Mobile in-car	80 dBµV/m	88 dBµV/m	94 dBµV/m
B1 – Light indoor	78 dBµV/m	87 dBµV/m	92 dBµV/m
B2 – Deep indoor	85 dBµV/m	94 dBµV/m	99 dBµV/m

Table 17: Required median field strength at 1.5m, for a DVB-T service, at 698MHz, 8MHz bandwidth, „good" quality of coverage

DVB-T	QPSK 1/2	16QAM 2/3	64QAM 2/3
C – Mobile roof-top	61 dBµV/m	69 dBµV/m	75 dBµV/m
A – Outdoor	59 dBµV/m	68 dBµV/m	73 dBµV/m
D – Mobile in-car	75 dBµV/m	83 dBµV/m	89 dBµV/m
B1 – Light indoor	69 dBµV/m	78 dBµV/m	83 dBµV/m
B2 – Deep indoor	76 dBµV/m	85 dBµV/m	90 dBµV/m

Table 18: Required median field strength at 1.5m, for a DVB-T service, at 698MHz, 8MHz bandwidth, „acceptable" quality of coverage

	DVB-T	QPSK 1/2	16QAM 2/3	64QAM 2/3
BMCO_I	- Acceptable outdoor pedestrian - Acceptable mobile roof-top	61 dBµV/m	69 dBµV/m	59 dBµV/m
BMCO_II	- Good mobile roof-top - Good outdoor pedestrian	67 dBµV/m	75 dBµV/m	81 dBµV/m
BMCO_III	- Acceptable Light indoor - Acceptable mobile incar	75 dBµV/m	83 dBµV/m	89 dBµV/m
BMCO_IV	- Good mobile in-car or - Acceptable deep indoor - Good light indoor	80 dBµV/m	88 dBµV/m	94 dBµV/m
BMCO_V	- Good deep indoor	85 dBµV/m	94 dBµV/m	99 dBµV/m

Table 19: Required median field strength at 1.5m, for a DVB-T service, at 698MHz, 8MHz bandwidth, by class of coverage

7.2. DVB-H

DVB-H	QPSK ½ MPE FEC 3/4	QPSK 2/3 MPE FEC 3/4	16QAM ½ MPE FEC 3/4	16QAM 2/3 MPE FEC 3/4
C – Mobile roof-top	61 dBµV/m	64 dBµV/m	67 dBµV/m	70 dBµV/m
A – Outdoor	62 dBµV/m	65 dBµV/m	68 dBµV/m	71 dBµV/m
D – Mobile in-car	74 dBµV/m	77 dBµV/m	80 dBµV/m	83 dBµV/m
B1 – Light indoor	77 dBµV/m	80 dBµV/m	83 dBµV/m	86 dBµV/m
B2 – Deep indoor	84 dBµV/m	87 dBµV/m	90 dBµV/m	93 dBµV/m

Table 20: Required median field strength at 1.5m, for a DVB-H service, at 698MHz, 8MHz bandwidth, „good" quality of coverage

DVB-H	QPSK ½ MPE FEC 3/4	QPSK 2/3 MPE FEC 3/4	16QAM ½ MPE FEC 3/4	16QAM 2/3 MPE FEC 3/4
C – Mobile roof-top	55 dBµV/m	58 dBµV/m	61 dBµV/m	64 dBµV/m
A – Outdoor	55 dBµV/m	58 dBµV/m	61 dBµV/m	64 dBµV/m
D – Mobile in-car	68 dBµV/m	71 dBµV/m	74 dBµV/m	77 dBµV/m
B1 – Light indoor	68 dBµV/m	71 dBµV/m	74 dBµV/m	77 dBµV/m
B2 – Deep indoor	75 dBµV/m	78 dBµV/m	81 dBµV/m	84 dBµV/m

Table 21: Required median field strength at 1.5m, for a DVB-H service, at 698MHz, 8MHz bandwidth, „acceptable" quality of coverage

	DVB-H	QPSK ½ MPE FEC 3/4	QPSK 2/3 MPE FEC 3/4	16QAM ½ MPE FEC 3/4	16QAM 2/3 MPE FEC 3/4
BMCO_I	- Acceptable outdoor pedestrian - Acceptable mobile roof-top	55 dBµV/m	58 dBµV/m	61 dBµV/m	64 dBµV/m
BMCO_II	- Good mobile roof-top - Good outdoor pedestrian	62 dBµV/m	65 dBµV/m	68 dBµV/m	71 dBµV/m
BMCO_III	- Acceptable Light indoor - Acceptable mobile incar	68 dBµV/m	71 dBµV/m	74 dBµV/m	77 dBµV/m
BMCO_IV	- Good mobile in-car or - Acceptable deep indoor - Good light indoor	77 dBµV/m	80 dBµV/m	83 dBµV/m	86 dBµV/m
BMCO_V	- Good deep indoor	84 dBµV/m	87 dBµV/m	90 dBµV/m	93 dBµV/m

Table 22: Required median field strength at 1.5m, for a DVB-H service, at 698MHz, 8MHz bandwidth, by class of coverage

7.3. MediaFLO

MediaFLO	MODE 1 QPSK ½	MODE 2 16QAM 1/3	MODE 7 QPSK 1/2 - BASE	MODE 7 QPSK 1/2 Enhanced
C – Mobile roof-top	57 dBµV/m	59 dBµV/m	60 dBµV/m	64 dBµV/m
A – Outdoor	60 dBµV/m	62 dBµV/m	63 dBµV/m	68 dBµV/m
D – Mobile in-car	72 dBµV/m	74 dBµV/m	75 dBµV/m	80 dBµV/m
B1 – Light indoor	75 dBµV/m	77 dBµV/m	78 dBµV/m	82 dBµV/m
B2 – Deep indoor	82 dBµV/m	84 dBµV/m	85 dBµV/m	89 dBµV/m

Table 23: Required median field strength at 1.5m, for a MediaFLO service, at 698MHz, 8MHz bandwidth, „good" quality of coverage

MediaFLO	MODE 1 QPSK ½	MODE 2 16QAM 1/3	MODE 7 QPSK 1/2 - BASE	MODE 7 - QPSK 1/2 - Enhanced
C – Mobile roof-top	51 dBµV/m	53 dBµV/m	54 dBµV/m	59 dBµV/m
A – Outdoor	54 dBµV/m	56 dBµV/m	57 dBµV/m	62 dBµV/m
D – Mobile in-car	66 dBµV/m	68 dBµV/m	69 dBµV/m	74 dBµV/m
B1 – Light indoor	66 dBµV/m	68 dBµV/m	69 dBµV/m	74 dBµV/m
B2 – Deep indoor	73 dBµV/m	75 dBµV/m	76 dBµV/m	80 dBµV/m

Table 24: Required median field strength at 1.5m, for a MediaFLO service, at 698MHz, 8MHz bandwidth, „acceptable" quality of coverage

	MediaFLO	MODE 1 QPSK ½	MODE 2 16QAM 1/3	MODE 7 QPSK 1/2 BASE	MODE 7 QPSK 1/2 Enhanced
BMCO_I	- Acceptable outdoor pedestrian - Acceptable mobile roof-top	54 dBµV/m	56 BµV/m	57 dBµV/m	62 dBµV/m
BMCO_II	- Good mobile roof-top - Good outdoor pedestrian	60 dBµV/m	62 dBµV/m	63 dBµV/m	68 dBµV/m
BMCO_III	- Acceptable Light indoor - Acceptable mobile incar	66 dBµV/m	68 dBµV/m	69 dBµV/m	73 dBµV/m
BMCO_IV	- Good mobile in-car or - Acceptable deep indoor - Good light indoor	75 dBµV/m	77 dBµV/m	78 dBµV/m	82 dBµV/m
BMCO_V	- Good deep indoor	82 dBµV/m	84 dBµV/m	85 dBµV/m	89 dBµV/m

Table 25: Required median field strength at 1.5m, for a MediaFLO service, at 600MHz, 8MHz bandwidth, by class of coverage

7.4. T-DMB

Mode I and mode II at protection level 3A are respectively used for VHF and L-band.

For L-Band, two cases are provided (see section 4.4):

- field strength for future terminals : 0dBi antenna gain and 3.5 dB noise figure
- field strength for current terminals : -5dBi antenna gain and 7 dB noise figure

	VHF 225 MHz	**L-Band 1470 MHz**	**L-Band currently 1470 MHz**
T-DMB	**Mode I PL-3A**	**Mode II PL-3A**	**Mode II PL-3A**
Class C	52 dBµV/m	63 dBµV/m	67 dBµV/m
Class A	61 dBµV/m	58 dBµV/m	67 dBµV/m
Class D	72 dBµV/m	70 dBµV/m	79 dBµV/m
Class B1	72 dBµV/m	74 dBµV/m	83 dBµV/m
Class B2	79 dBµV/m	81 dBµV/m	90 dBµV/m

Table 26: Required median field strength at 1.5m, for a T-DMB service, „good" quality of coverage

	VHF 225 MHz	**L-Band 1470 MHz**	**L-Band currently 1470 MHz**
T-DMB	**Mode I PL-3A**	**Mode II PL-3A**	**Mode II PL-3A**
Class C	47 dBµV/m	57 dBµV/m	61 dBµV/m
Class A	54 dBµV/m	52 dBµV/m	61 dBµV/m
Class D	67 dBµV/m	64 dBµV/m	73 dBµV/m
Class B1	64 dBµV/m	66 dBµV/m	75 dBµV/m
Class B2	70 dBµV/m	72 dBµV/m	81 dBµV/m

Table 27: Required median field strength at 1.5m, for a T-DMB service, „acceptable" quality of coverage

		VHF 225 MHz	L-Band 1470 MHz	L-Band currently 1470 MHz
	T-DMB	**Mode I PL-3A**	**Mode II PL-3A**	**Mode II PL-3°**
BMCO_I	- Acceptable outdoor pedestrian - Acceptable mobile roof-top	54 dBµV/m	57 dBµV/m	61 dBµV/m
BMCO_II	- Good mobile roof-top - Good outdoor pedestrian	61 dBµV/m	63 dBµV/m	67 dBµV/m
BMCO_III	- Acceptable Light indoor - Acceptable mobile incar	67 dBµV/m	66 dBµV/m	75 dBµV/m
BMCO_IV	- Good mobile in-car or - Acceptable deep indoor - Good light indoor	72 dBµV/m	74 dBµV/m	83 dBµV/m
BMCO_V	- Good deep indoor	79 dBµV/m	81 dBµV/m	90 dBµV/m

Table 28: Required median field strength at 1.5m, for a T-DMB service, by class of coverage

7.5. DVB-SH

The field strengths below assume a terrestrial reception (CGC – Complementary Ground Component). An antenna gain of -3 dBi in class A,B,D is used for the calculation below:

DVB-SH	**QPSK TC 1/3**	**QPSK 1/2**	**16QAM 1/3**
C – Mobile roof-top	56 dBµV/m	59 dBµV/m	62 dBµV/m
A – outdoor	57 dBµV/m	61 dBµV/m	63 dBµV/m
D – Mobile in-car	68 dBµV/m	71 dBµV/m	74 dBµV/m
B1 – Light indoor	75 dBµV/m	78 dBµV/m	81 dBµV/m
B2 – Deep indoor	81 dBµV/m	84 dBµV/m	87 dBµV/m

Table 29: Required median field strength at 1.5m, for a DVB-SH service, at 2200 MHz, 5MHz bandwidth, „good" quality of coverage without Rx diversity

DVB-SH	QPSK TC 1/3	QPSK TC 1/2	16QAM 1/3
C – Mobile roof-top	50 dBµV/m	54 dBµV/m	56 dBµV/m
A – outdoor	51 dBµV/m	55 dBµV/m	57 dBµV/m
D – Mobile in-car	62 dBµV/m	66 dBµV/m	68 dBµV/m
B1 – Light indoor	66 dBµV/m	70 dBµV/m	72 dBµV/m
B2 – Deep indoor	72 dBµV/m	75 dBµV/m	78 dBµV/m

Table 30: Required median field strength at 1.5m, for a DVB-SH service, at 2200 MHz, 5MHz bandwidth, „acceptable " quality of coverage without Rx diversity

Tentative application of BMCO classes to DVB-SH:

	DVB-SH	QPSK TC 1/3	QPSK TC 1/2	16QAM 1/3
BMCO_I	- Acceptable outdoor pedestrian - Acceptable mobile roof-top	51 dBµV/m	53 dBµV/m	57 dBµV/m
BMCO_II	- Good mobile roof-top - Good outdoor pedestrian	57 dBµV/m	61 dBµV/m	63 dBµV/m
BMCO_III	- Acceptable Light indoor - Acceptable mobile incar	66 dBµV/m	70 dBµV/m	72 dBµV/m
BMCO_IV	- Good mobile in-car - Acceptable deep indoor - Good light indoor	75 dBµV/m	78 dBµV/m	81 dBµV/m
BMCO_V	- Good deep indoor	81 dBµV/m	84 dBµV/m	87 dBµV/m

Table 31: Required median field strength at 1.5m, for a DVB-SH service, at 2200MHz, 5MHz bandwidth, by class of coverage without Rx diversity

Note that in the case of DVB-SH using S–band, reception diversity is a feature available for handset terminals.

As an example, using expected reception diversity (section 5.2), field strength levels are[33]

- 2.5 dB lower for in-car reception in BMCO class III (e.g. 63.5 dBµV/m with QPSK TC 1/3)
- 6 dB lower for BMCO class V (e.g. 75 dBµV/m for BMCO_V with QPSK TC 1/3)

[33] Measured with experimental receivers. To be confirmed using the first integrated handheld terminals.

7.6. *Global comparison of specific configurations*

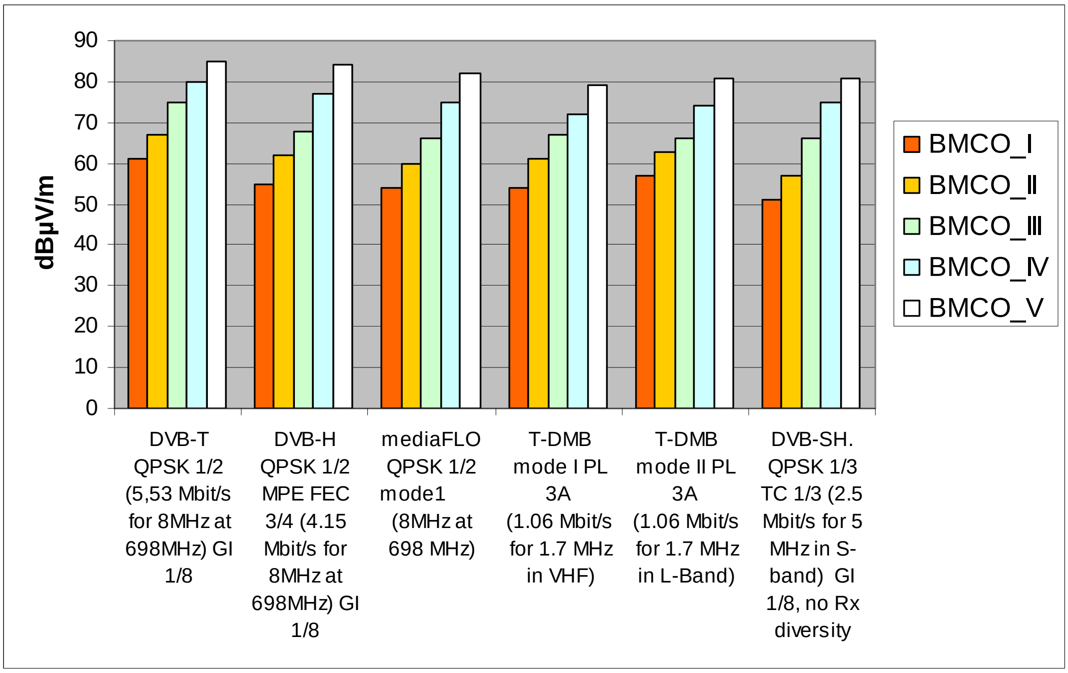

Figure 4: Illustration of minimum field strengths for BMCO coverage classes in various technologies and configurations.

8. Reference minimum terminal sensitivity

This section provides the required terminal sensitivity expressed as the minimum median field strength values required, in laboratory conditions. It considers terminals with built-in antenna, because for such type of terminals the antenna is the only interface to verify the sensitivity in terms of field strength. For other types of terminals (Class C – car roof-top antenna) the characteristics of antenna (Gain), the Noise figure and minimum C/N can be measured separately to derive the required sensitivity.

The required field strengths given below assume a laboratory environment (at step 2 of link budget, in section 3): no penetration losses nor combined field strength variations nor other losses are taken into account. In case of terminals with an external antenna, the field strengths given below can be decreased by the difference of antenna gain (section 4.4, Table 5).

8.1. DVB-T

Mode	QPSK 1/2			16 QAM 2/3			64 QAM 2/3		
Ch. Profile	PO	PI	TU6	PO	PI	TU6	PO	PI	TU6
474 MHz	53	51	57	62	60	65	67	65	71
698 MHz	53	52	58	62	61	66	67	65	72
858 MHz	53	51	57	62	60	65	67	65	71

Table 32: Required DVB-T terminal sensitivity (dBµV/m)

Notes:
- 8 MHz Bandwidth
- the "other losses" given in section 4.5 are not taken into account.
- in the case of non connected terminals, the above values should be 2 dB lower due to better noise figure (section 6.2).

8.2. DVB-H

Mode	QPSK 1/2			QPSK 2/3			16 QAM 1/2			16 QAM 2/3		
Ch. Profile	PO	PI	TU6	PO	PI	TU6	PO	PI	TU6	PO	PI	TU6
474 MHz	49	50	51	52	53	54	55	56	57	58	59	60
698 MHz	50	51	51	53	54	54	56	57	57	59	60	60
858 MHz	49	50	51	52	53	54	55	56	57	58	59	60

Table 33: Required DVB-H terminal sensitivity (dBµV/m)

Notes:
- 8 MHz Bandwidth
- the "other losses" given in section 4.5 are not taken into account.
- in the case of non connected terminals, the above values should be 2 dB lower due to better noise figure (section 6.2).

8.3. T-DMB

Mode	Mode I/II Level 3A		
Ch. Profile	PO	PI	TU6
225 MHz	47	47	48
1470 MHz	53	53	54

Table 34: Required T-DMB terminal sensitivity (dBµV/m)

Notes:
- 1.7 MHz Bandwidth
- Antenna gain used is −5 dBi in L-band
- the "other losses" given in section 4.5 are not taken into account.

8.4. DVB-SH

Mode	QPSK TC 1/3	QPSK TC 1/2	16 QAM TC 1/3
Ch. Profile	TU6	TU6	TU6
2182 MHz	48	51	54

Table 35: Required DVB-SH terminal sensitivity (dBµV/m)

Notes:
- 5 MHz Bandwidth
- the "other losses" given in section 4.5 are not taken into account.
- A 4.5 dB noise factor is assumed, and corresponds to receiver with a LNA in the RF front-end. In case the RF front-end does not contain such LNA the above values shall be 1.5 dB higher.

9. Conclusion

The link budget model for mobile television services presented in this paper is a common methodology that is applicable to mobile TV technologies which are available today: DVB-T, DVB-H, MediaFLO, T-DMB, DVB-SH. The key parameters are provided, for each specific technology.

This reference link budget is intended to help broadcasters in their network planning and network dimensions estimation. Five BMCO coverage classes are defined, accounting for groups of usage scenarios with similar field strength levels requirements.

Reference planning values for all usage scenarios (outdoor, indoor, pedestrian and in-car mobility) are provided. These values are indicative and may be further refined depending on the specific characteristics of technologies, coverage requirements and broadcasters goals.

10. References

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11. On bmcoforum "Broadcast Network Structure and Coverage Expectations" Group

One of the key success factors and at the same time one of most cost sensitive aspects of mobile broadcast services is mobile indoor reception. In pilots experiences will be gathered by the broadcast network operators on the number of transmitters and repeaters, the parameter settings, antenna gain of terminals etc.

This "Broadcast Network Structure and Coverage Expectations" work item targets on

- Analysis of the influence of broadcast network structure and parameters on coverage expectations
- Exchange of experiences from national trials and other testbeds as well as from simulations

The following members of the "Broadcast Network Structure and Coverage Expectations" Group contributed to this study:

- Alcatel-Lucent
- DiBcom
- Institut für Rundfunktechnik
- Media Broadcast
- Nokia
- Qualcomm
- TDF
- Teracom
- Technical University of Braunschweig

Annex: Area vs. Edge Coverage

Area coverage can map to edge coverage.

Table 25 below gives a mapping example, using a field strength variation of 5.5 dB and a propagation slope of 3.5. Propagation slope characterises attenuation of the environment as an exponent of (1/r), r being the distance to the transmitter. Propagation slope equals 2 (20dB/dec) in free space and 3.5 (35dB/dec) in a typical urban environment.

area %	84,0%	87,3%	**90,3%**	92,6%	94,6%	96,0%	97,3%	98,1%
edge %	60,1%	67,4%	**73,8%**	79,1%	84,1%	88,2%	91,0%	93,6%
area %	**98,7%**	99,1%	99,5%	99,7%	99,8%	99,9%	99,9%	
edge %	**95,7%**	96,9%	98,2%	99,0%	99,1%	99,7%	99,8%	

Table 36: Area vs. Edge coverage

Mobile Broadcast Technologies

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Update 02/2009

Editors:
Jean-Jacques Delmas (TDF)
Pierre Bretillon (TDF)

Broadcast Mobile Convergence Forum
bmcoforum e.V.
Attilastr. 61-67
12105 Berlin
Germany
Tel: +49 30 255 680-0
Fax: +49 30 255 680-99
info@**bmco**forum.org
www.**bmco**forum.org