DVB-T

— network structures and costs for full coverage

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Due to the high penetration of cable and satellite TV services in Germany, the take-up of terrestrial TV is currently less than 10% (at least for the main receiver in each home), and with a slowing tendency. Therefore, in order to reverse this trend, viewers of future DVB-T services will have to be offered new incentives such as portable indoor reception, without the need for a classical roof-top antenna.

In the present study, the extent to which full area coverage could be achieved – for portable indoor reception – was investigated in the Schleswig-Holstein region. During the transition period, the level of the effective radiated transmitter power will have to be reduced in accordance with the Chester agreement. It is shown that, after conversion of the existing transmitter network in Schleswig-Holstein, a DVB-T coverage probability of 70% could be reached.

Higher coverage probabilities, for portable indoor reception, can only be realized in a cost-effective way by the use of single-frequency networks. However, this implies a revision of the Stockholm Agreement 1961.

Introduction

The existing analogue transmitter networks – for both sound broadcasting and television – were largely designed for full area coverage. The transmitter density required to achieve this has represented a considerable factor in the cost of programme distribution. In Germany, for example, 320 main transmitters and more than 8,000 fill-in stations (relays) are required to provide national coverage of the three public-service TV programmes (ARD, ZDF and the third programme). The transition to digital terrestrial television is of course connected with the wish to save on the cost of programme distribution. In the German IDR (Initiative Digital Radio), the consensus is that typically 50% of the programme distribution costs could be saved, provided that no – or few – additional transmitters were needed to provide national DAB coverage using the existing network of FM transmitter sites.

Cost analyses for specific transmitter network structures have recently been carried out in order to estimate the total costs involved in the introduction of DVB-T services in Germany. In 1999, the “Landesanstalt für Kommunikation” (LfK) in Baden-Wuerttemberg published the results of an investigation, containing the costs for DVB-T coverage of the Stuttgart region. Because of the difficult topography in this area, it was not possible to extrapolate the results to estimate the network structure required to provide national coverage of Germany. Instead, the costs for national programme distribution were derived after carrying out a further investigation in the federal state of Schleswig-Holstein, where the terrain is – to a large extent – rather flat. Thus the application of simpler field-strength prediction methods (e.g. ITU-R Rec. P.370 [1]) could be applied here.

The degree of coverage achievable, with a chosen transmitter network structure, largely depends on the chosen DVB-T variant. The variant 16-QAM with code rate 2/3 was chosen for the investigation in Schleswig-Holstein. This variant is based on a C/N value of 17 dB and offers a net bit-rate of 13.27 Mbit/s. It is expected that this bit-rate will allow four digital programmes to be carried within an 8 MHz TV channel.

Analogue coverage in Schleswig-Holstein

The starting point for our considerations was the present analogue coverage of the Second Programme (ZDF) in Schleswig-Holstein. It was shown that full area DVB-T coverage could be achieved with the nine analogue TV transmitters which are in operation in this federal state. The coverage boundary is based on the so-called *minimum usable field strength contour* (noise-limited), which determines the coverage area in the absence of interference. Since no interference is considered, this value is in general too optimistic.

Table 1
Analogue and digital transmitter powers.

Transmitter site	Channel (analogue and digital MFN)	Analogue transmitter power (kW)	Digital transmitter power, MFN (kW)	Digital transmitter power, SFN (kW)
Cuxhaven	24	330	66	50
Eiderstedt	31	500	100	100
Eutin	21	500	100	100
Flensburg	39	250	50	50
Hamburg	30	500	100	100
Kiel	35	250	50	50
Lübeck	23	250	50	50
Niebüll	34	200	40	50
Schleswig	26	100	20	50
Itzehoe	26	-	-	50

The description of the coverage boundaries by the so-called *interference contour*, taking into account all potential sources of interference, in general approaches the actual situation better. *Fig. 1* [1] shows the analogue coverage in the Schleswig-Holstein region, taking interference into account. It shows clearly that, based on the transmitter powers given in *Table 1*, the theoretical determination of the interference contours leads to coverage deficits in the area north-west of Hamburg (Neumünster-Heide-Itzehoe).

The reasons for this are due to the assumed topography. The field-strength prediction method that was used – based on ITU-R Recommendation P.370 [1] – assumes, among other things, a predetermined ground roughness that is described by the so-called Δh value. This value is taken as 50 m. The majority of the terrain in Schleswig-

1. The eight figures (i.e. maps) accompanying this article are displayed in *Appendix A*, with a reasonable image quality that is consistent with keeping the overall PDF file size small. By clicking on any of these maps, a higher-quality JPEG image of each map can be downloaded: the largest of these JPEG images is around 500KB.

Holstein, however, has a Δh value of 10 m. This results in a considerable error margin when calculating the wanted field strengths and, in practice, these coverage deficits do not exist.

Digital coverage

Considering the digital coverage, one must distinguish between the different phases: the introduction phase, the transition period and the final state.

During the introduction phase and the transition period, transmitters are generally converted from analogue to digital according to the Chester Agreement (CH97). In this case, a single analogue transmitter can be converted into one or several digital transmitters, operating in a small-cell SFN. Also, additional frequencies (e.g. channels above ch. 60) can be used. The conversion of analogue transmitters into digital transmitters, according to the Chester Agreement, requires at least a 7 dB reduction in the transmitted power *(Table 1)*. After the conversion of all transmitters, this reduction is no longer required, provided all the digital transmitters increase their ERP by this amount.

In the final state, the full area coverage will mainly be realized by large-area SFNs. This aim can only be achieved by a revision of the Stockholm 1961 Agreement since, as mentioned above, the current network structure only allows for small-cell SFNs, and further frequency resources in general are not available. It is most unlikely that a revised Stockholm Agreement will come into force before the year 2010. Therefore, a higher number of programmes (the foreseen target is currently 20 - 24 programmes in total) cannot be realized until then. During the transition period, it will not be possible to radiate more than 12 programmes from each transmitter, unless higher modulation schemes are used. Full area coverage at that stage can only be achieved with a moderate coverage probability (cp ≈ 70%).

Transition period

The transition period which was taken as a basis in the LfK study should first be considered. With the coverage aim of providing “portable indoor reception" and using the DVB-T variant 16-QAM, R=2/3, the values for the minimum median usable field strength (at 10m agl) are quite high *(see Table 2)* and clearly above those for analogue television. *Fig. 2* shows the DVB-T coverage of Schleswig-Holstein using nine transmitters, on the basis of the ITU-R propagation curves for 70% coverage probability. Both the minimum usable field strength and the interference contours are represented. Significant differences between both contours are hardly noticeable. For a coverage probability of 70%, the theoretical coverage gaps are larger than those of analogue TV. In *Fig. 3*, the coverage for 95% coverage probability is additionally shown (inner contours).

Table 2
Minimum usable field-strength values for DVB-T (16-QAM, R = 2/3) in UHF bands IV and V *(values for band V are in brackets)*.

	Minimum median usable field strength (dBμV/m)	
	Fixed reception	Portable indoor reception
	Antenna height = 10m	Reference antenna height = 10m (ITU-R Rec. P.370)
Coverage probability 70%	44 (48)	71 (75)
Coverage probability 95%	50 (54)	81 (85)

If the coverage calculation is performed in conjunction with a topographical database which considers the more favourable propagation conditions that are applicable in Schleswig-Holstein, then more realistic statements can be made. *Fig. 4* shows that for a coverage probability of 70%, only small coverage deficits may be expected. On the other hand, the available transmitter network structure is not sufficient to provide for a DVB-T coverage probability of 95% *(Fig. 5)*. The DVB-T coverage assuming the use of roof-top antennas (i.e. stationary reception with a coverage probability of 95%) is represented in *Fig. 6*. In spite of the transmitter power being reduced by around 7 dB during this phase, the entire area is well covered.

Final state

After the transition period, i.e. when the results of the revised ST61 conference come into force, the transmitters should become operational in an SFN. Due to the network gain which is normal within SFNs, a clear improvement in the coverage situation can be expected. The coverage map shown in *Fig. 7*, which assumes portable indoor reception, is based on the situation where all transmitters are operated as an SFN. The transmitter powers are between 50 and 100 kW *(Table 1)*. On account of the dimensions of Schleswig-Holstein, self interference is already noticeable in some areas. It can be expected that a subdivision of the area will improve the situation to a great extent.

A further (tenth) transmitter was introduced at Itzehoe (north west of Hamburg). This transmitter provides clear improvements in the area as shown in *Fig. 8*. Time-delay optimization may improve the results even further.

Costs

The costs to be expected will largely be influenced by the degree of coverage and the network structure envisaged. Due to the linearity requirements of the COFDM signal, a so called “back-off” in the order of 6 dB is deemed to be necessary for the transmitter final stage, i.e. the nominal output power of the final transmitter stage should be 6 dB above the operational transmitter power. According to the Chester Agreement the digital transmitter power should be at least 7 dB below the analogue transmitter power, i.e. the nominal transmitter output power for analogue and digital operation is nearly the same. Under this condition and neglecting the cost of the multiplexer, in a first approximation the costs at the transmitter site will remain constant. However, the extension of the infrastructure (power supply, antennas, buildings) which may be necessary at certain transmitter sites, would lead to a corresponding increase in the costs.

For a coverage probability of 70%, the cost factor for one digital programme would be 25% of that of an analogue one. For higher degrees of coverage, in the case of MFN structures this value will increase proportionally with the number of transmitters. Compared to MFNs, the possible transition to SFNs – after the Revision of ST 61 – would lead to greater improvements at the higher degrees of coverage. However, an investigation of more difficult topographical areas is required to ascertain what the relevant cost factors would be.

Abbreviations

16-QAM 16-state quadrature amplitude modulation
agl Above ground level
C/N Carrier-to-noise ratio
COFDM Coded orthogonal frequency division multiplex
DAB Digital Audio Broadcasting
DVB-T Digital Video Broadcasting - Terrestrial
ERP Effective radiated power
ITU International Telecommunication Union
ITU-R ITU - Radiocommunication Sector
JPEG Joint Photographic Experts Group
MFN Multi-frequency network
NW North-west
PDF (Adobe) portable document format
SFN Single-frequency network

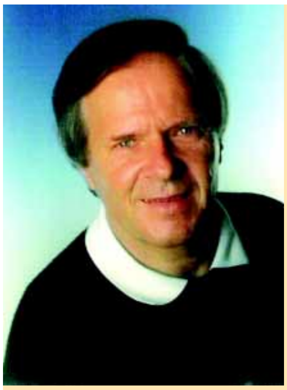
Conclusions

On the basis of the assumed planning parameters and the use of an MFN to cover the federal state of Schleswig-Holstein, it can be expected that satisfactory full area coverage for portable indoor reception of DVB-T may be achieved with probabilities of 70%. With the existing transmitter network, full area coverage with higher probabilities (95%) can only be achieved for stationary reception using roof-top antennas.

With the MFN concept, the realization of higher coverage probabilities during the transition period can only be envisaged in a financially justifiable framework. This could possibly lead to transmitter network structures which may not be required in the final state, i.e. the realization of SFNs. Operating the present transmitter network as an SFN, a division of Schleswig-Holstein into sub-regions may be advisable, to reduce the system-dependent self interference.

On the basis of the results obtained, some statements concerning the costs during the transition period can be made. In the case of an MFN, these costs greatly depend on the degree of coverage envisaged. With the reception mode "portable indoor" and coverage probabilities up to 70%, the lower limit of the expected costs would be in the order of 25% per programme, when compared with one existing analogue programme.

On account of the different topographical terrain within Germany, the results cannot simply be extrapolated to other federal states.



Gerd Petke is Head of the Frequency Planning and Management Section of the Institut für Rundfunktechnik (IRT). After having studied RF-transmission techniques and telecommunications at the University of Hannover, he joined the IRT in 1971, where he was involved in all aspects of broadcasting transmission systems (radio and television). In 1984 he was appointed Head of the Frequency Planning and Management Section.

In connection with his continuous frequency planning activities, Mr Petke is involved in all planning aspects for future transmission systems, such as T-DAB and DVB-T, and in establishing sharing criteria between broadcasting and other services. He is an active participant in several international working groups of the EBU and the CEPT, dealing with aspects of terrestrial broadcasting.

Jürgen Frank, born in 1964, studied electrical engineering at the University of Stuttgart with an emphasis on telecommunications. After completing his studies in 1992, he joined the Institut für Rundfunktechnik (IRT) as a scientific employee in the specialist field of antenna systems and wave propagation. His special area there was the planning and implementation of measurements and system tests in the DAB radio channel.

Since 1996, Mr Frank has been a member of the IRT's Frequency Planning and Management Section, working on the planning of digital terrestrial transmission systems such as T-DAB and DVB-T.

Bibliography

[1] ITU-R Recommendation P.370: **VHF and UHF propagation curves for the frequency range from 30 MHz to 1 000 MHz. Broadcasting services**
http://www.itu.int/itudoc/itu-r/rec/p/index.html

Appendix A:
Coverage maps

The following maps have been produced at medium resolution (150dpi) and by using high JPEG compression — to keep the overall PDF file size of this article within manageable limits.

By clicking on any of these maps, you can download a higher-quality JPEG version of the map.

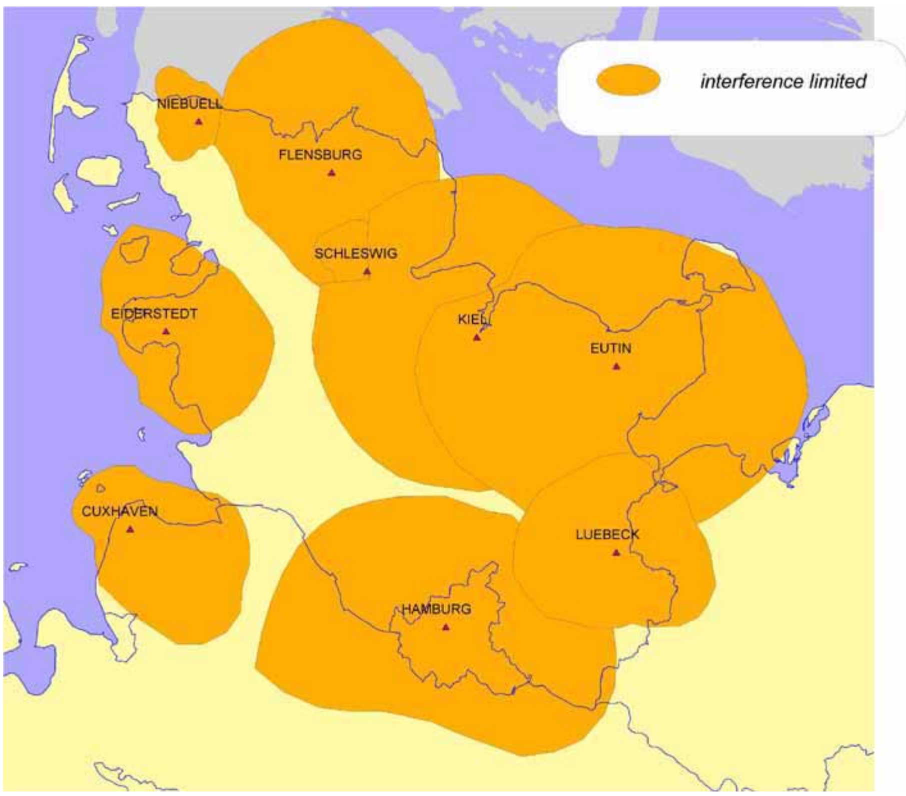


Figure 1
Analogue coverage in the Schleswig-Holstein region, taking interference into account.

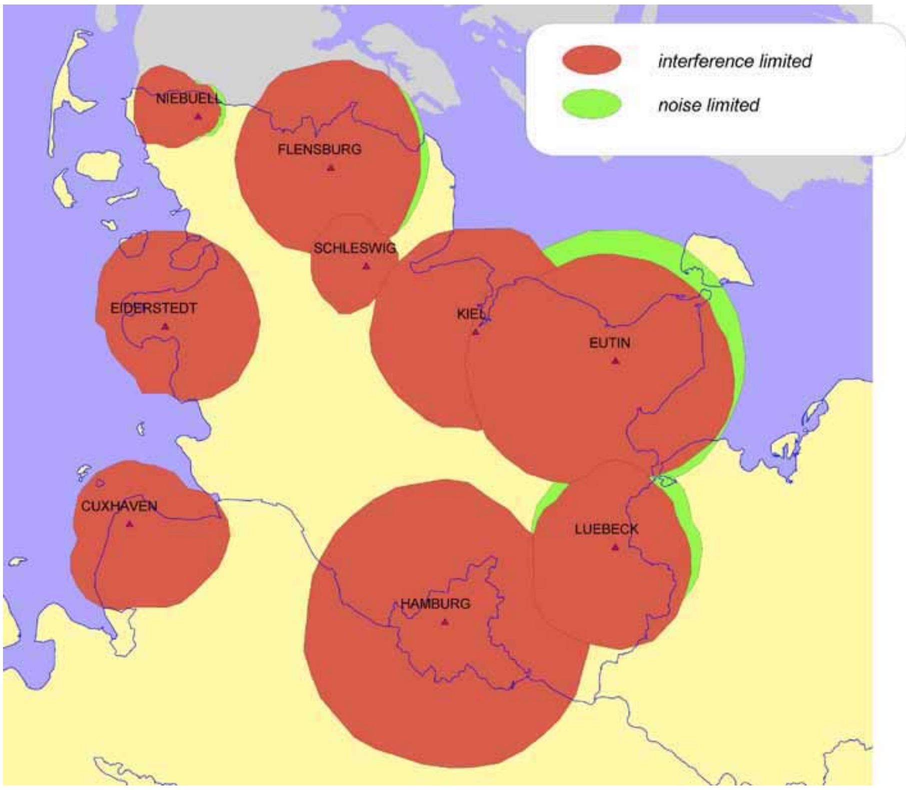


Figure 2
DVB-T coverage (for portable indoor reception) in the Schleswig-Holstein region using the DVB variant 16-QAM, R = 2/3, and showing the 70% probability contours.

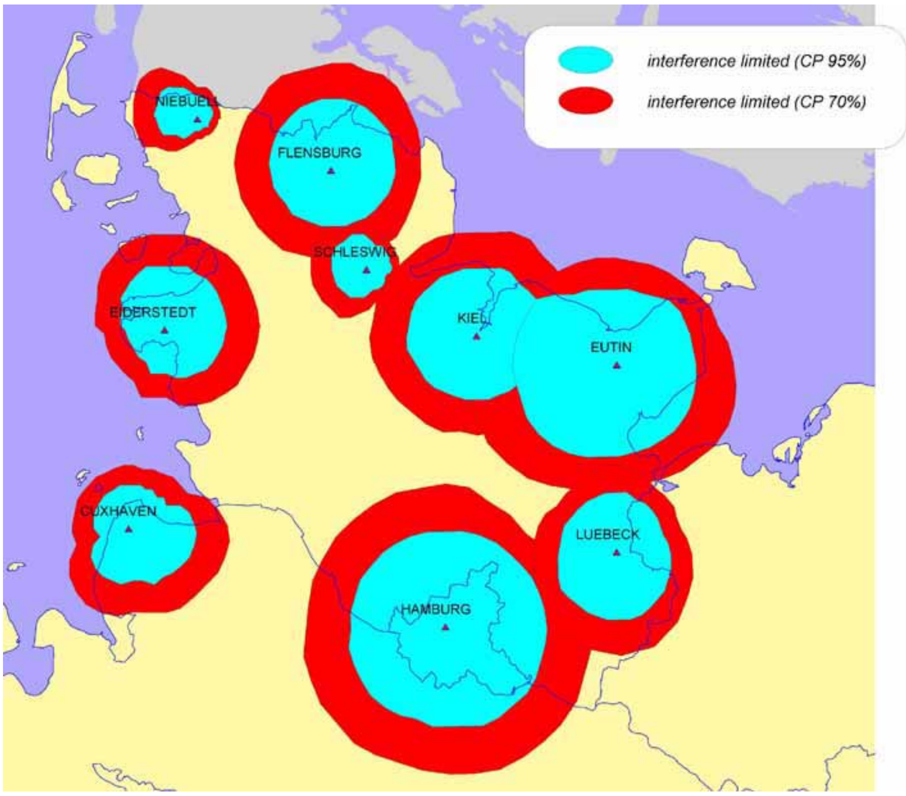


Figure 3
As Figure 2 but additionally showing the 95% probability contours.

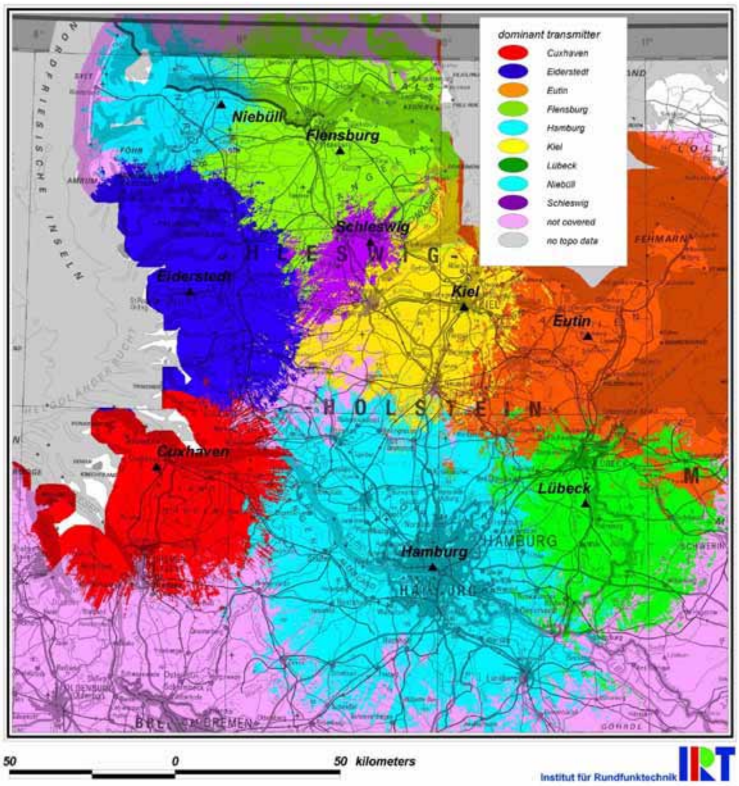


Figure 4 – Calculated DVB-T coverage for portable indoor reception (70% probability)
In this case, only small coverage deficits would be expected.

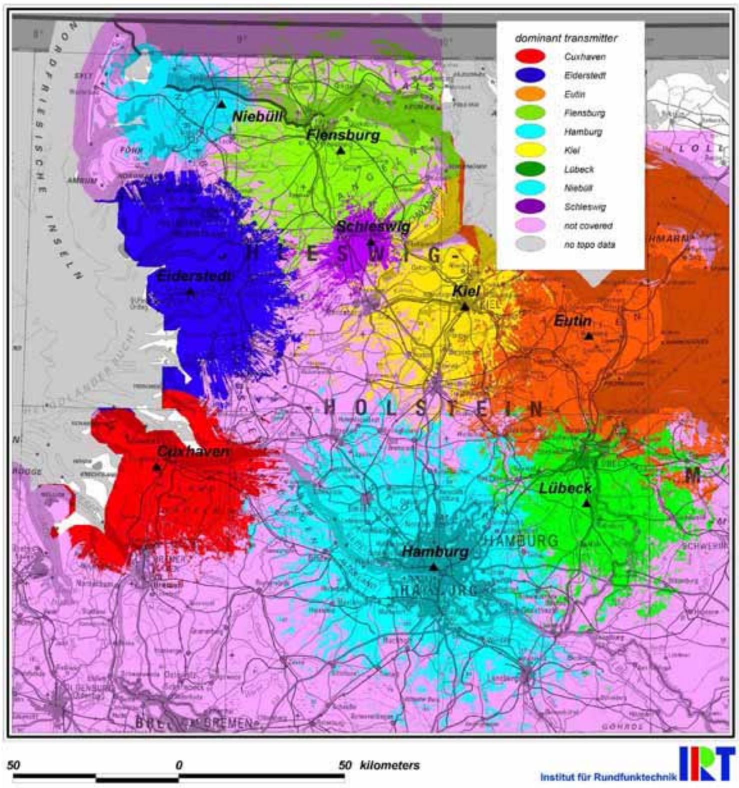


Figure 5 – Calculated DVB-T coverage for portable indoor reception (95% probability)
In this case, the existing infrastructure (with nine transmitters) would not be adequate.

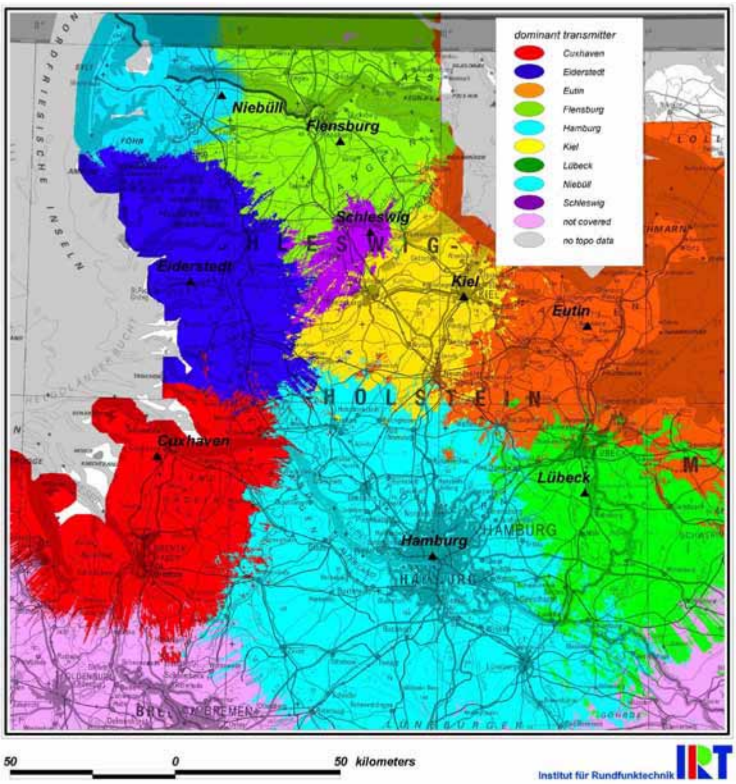


Figure 6 – Calculated DVB-T coverage for fixed-antenna reception (95% probability) Despite a 7dB reduction in transmitter power, the entire area is well covered.

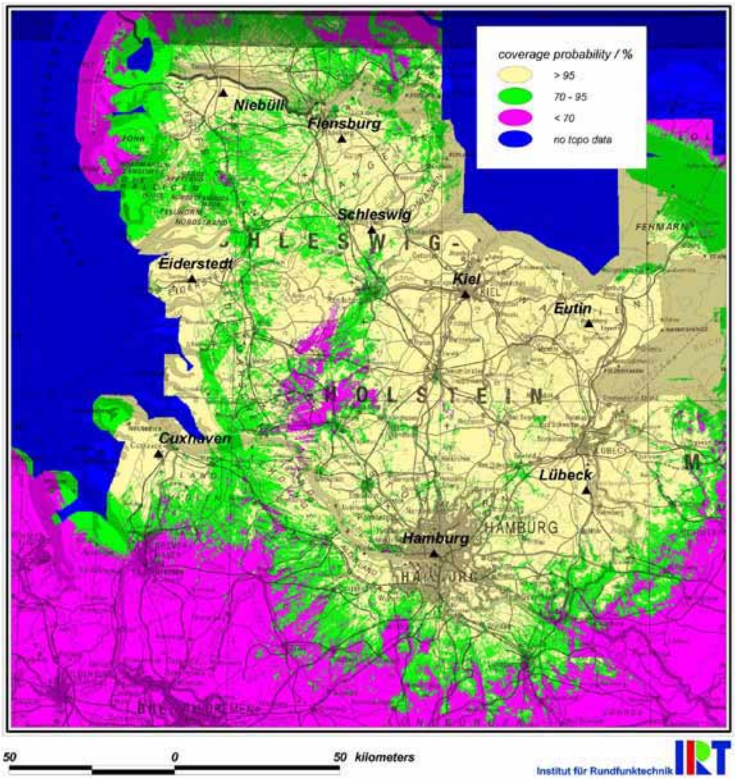


Figure 7 – Calculated DVB-T coverage for portable indoor reception (95% probability)
In this case, an SFN has been used, yielding significant coverage gains.

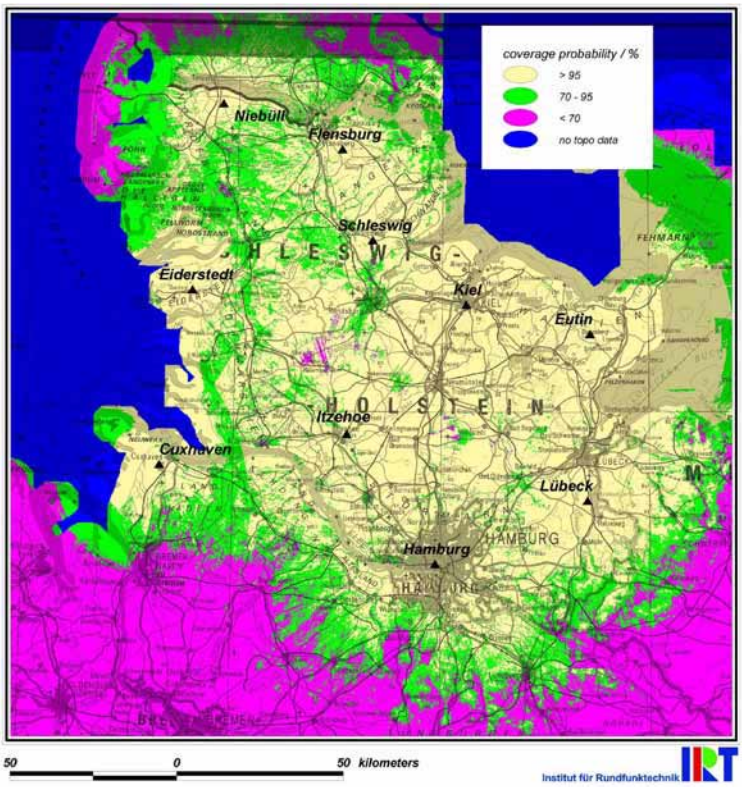


Figure 8 – Calculated DVB-T coverage for portable indoor reception (95% probability)
As Figure 7 but with an extra SFN transmitter to cover the Itzehoe area (NW of Hamburg).