Appendix A: Summary of Test Results from Germany and Austria

A.1 ANGA/IRT Study on Interference from Bidirectional Mobile Services into Cable TV Infrastructures

This is an English summary of the full report, which can be found in German at:
http://www.anga.de/uploads/media/2009-04-08_LTE-Kabel-Abschlussbericht_01.pdf

Resulting from the decisions of the ITU World Radiocommunications Conference 2007 and the proposed implementation of them by the German Department of Economics (the latter pending a confirmation by the German parliament) with regard to the future usage of the Digital Dividend, in Germany the frequency range from 790 MHz to 862 MHz will be made available for mobile broadband Internet when Broadcast use ceases.

Concerned at the potential impact on existing services carried across the TV cable infrastructure which consist of Television, Radio, Broadband Data, interactive services including video on demand and telephony the German association of cable network operators ANGA has identified the lack of a thorough understanding of the interference mechanisms which will come into play if the new services are implemented.

These fundamental changes require intensive technical research and an alignment of the relevant standards with the new environment. ANGA emphasized that while acknowledging the potential of improving the quality and availability of modern communication services by using the Digital Dividend, the consequences have to be balanced with the damage to existing services already in use by millions of customers.

Starting with a theoretical analysis of potential interfering effects of an LTE signal emitted in close proximity to the coaxial section of a Hybrid-Fibre-Cable (HFC) infrastructure and verifying those effects in lab and field environments, the ANGA/IRT study provides considerable evidence for the interference potential of mobile services in the frequency spectrum identified for the Digital Dividend.

Potential interference to the range of services identified above results from the fact that all over Europe the majority of HFC network operators use the full spectrum, up to 862 MHz in order to be able to satisfy the demand for analogue TV, Radio and digital triple play (TV, Internet access, telephony) and have used the band 790-862 MHz for many years.

The measurements show clearly, that massive disturbances of the cable signals is to be expected when exposed to an LTE signal. Operation of cable services would be impossible in the frequency range 790-862 MHz with the proposed RF transmission powers. It is irrelevant whether the interfering signal directly leaks into the cable network or if the ingress affects the end device, the viewer receives interference. However, due to different shielding properties and immunity requirements the end devices such as Set Top Box's (STBs) have been clearly identified as the most sensitive element of the cable infrastructure in the presence of a simulated LTE network in both up- and downlink transmissions.

European Norm EN 50083-8 determines the interference immunity of the cable network equipment to be 106 dBµV/m (for an interferer at a distance of 3 m to the outside wall of a building). Assuming a common value of 10 dB for the attenuation of a building this translates into an immunity threshold of 96 dBµV/m indoor in 3 m distance to the cable.

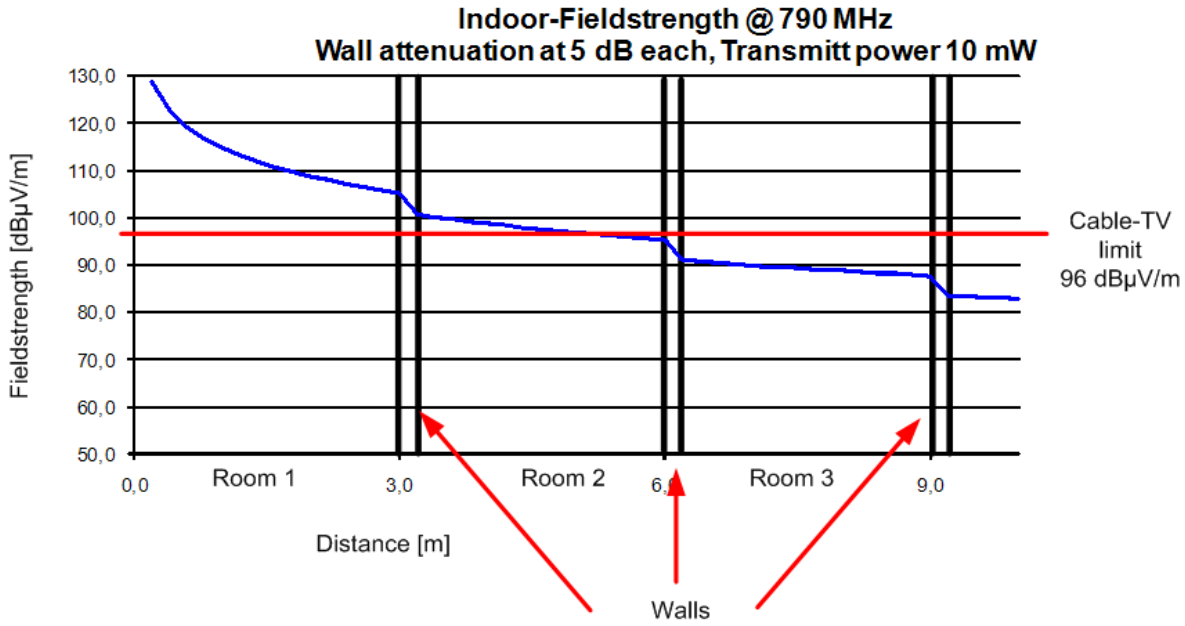


Figure A.1.1: Calculated indoor field strength of a transmission signal at 790 MHz

Figure A.1.1 shows the calculated graph of field strength for an isotropic emitter with an emission power of 10 mW at a frequency of 790 MHz. Walls with an attenuation of 5 dB each are placed in 3 m, 6 m and 9 m distance, respectively. The attenuation of indoor walls is assumed to be half the attenuation of the outside wall. Accumulation effects through reflections are not considered in this calculation. The threshold for cable networks of 96 dBµV/m at a distance of 3 m to the TV cable (indoor) is indicated by the red line. The figure shows conclusively, why interferences from mobile terminal devices would have such an extreme impact on cable service viewers as shown by the following results.

For set-top boxes, immunity of 125 dBµV/m (3 V/m is equal to 130 dBµV/m) from out-of-band interference is defined. In this context, out-of-band means that interference in the used channel (in-band) is not considered as an error condition. Immunity has to be provided only against leakage into neighbouring channels as described in EN 55020 (for ingress in the range of 150 kHz to 150 MHz, no ingress limits are defined outside of this range) and EN 55013 (for egress). Those standards establish a very low requirement of interference immunity for end user devices when compared with the requirement of 106 dBµV/m in EN 50083-8 for cable networks.

An important part of the ANGA/IRT study was the definition of a protection ratio within the cable infrastructure that related to the theoretical case of DVB-C signal disturbing another DVB-C signal in the same channel. This protection ratio was determined to be 24 dB. It finds practical application when comparing it to the protection ratio required for an LTE signal disturbing a DVB-C channel. It turned out that the LTE signal requires a protection ratio which is at least 7 dB higher and, thus, has to be defined at more than 31 dB.

For the test setup with a simulated LTE base station transmitting at the maximum power of 50 dBm visible disturbances of the cable TV reception were observed for analogue TV but not for DVB-C digital reception. The reason for this is believed to be that the set-top box's error protection algorithms are still able to cope with the disturbed signal, for the rather larger distance to the base station of about 85 m and the relatively high attenuation of the building due to its construction with armoured (metal) concrete elements. The interfering effect of the LTE downlink signal, however, could clearly be identified on the analogue TV picture as well as on the MER of the received digital signal modulated with 64 QAM. With higher modulation orders such as 256 QAM the interference would have had a more severe impact and would certainly have resulted in a visibly disturbed picture.

A mobile uplink station represented e.g. by a terminal device resulted in disturbances in all cases, even if the transmission equipment was placed behind a wall in the room next door and, thus, invisible to the DVB-C viewer. Even in the latter case, the average transmission power of the LTE mobile terminal exceeded the value where interference started to be visible by a factor of four. Scenarios with peak transmission power will lead to a total loss of service.

Setup 1 - Downlink	LTE transmitting power resulting in interference	
	80 m distance, vertical	
PAL reception	600 mW(erp) = 27,8 dBm	critical
DVB-C reception	240 W(erp) = 53,8 dBm	non-critical

Table A.1.1: Analogue TV subjected to LTE downlink interference

The table above shows that an analogue TV signal is already interfered with by a 600 mW (27.8 dBm) LTE downlink signal emitted in 80 m distance outside of the building. The digital cable TV signal could use the error protection mechanisms to still display a picture under these circumstances. Measurements showed, however, a decrease of relevant parameters such as MER, BER and PER.

Setup 2 – Uplink, same room	LTE transmitting power resulting in interference	
	2,5 m distance, vertical	Reference value: 125 mW = 21 dBm
PAL reception	0,3 mW(erp) = - 5 dBm	critical
DVB-C reception	2,5 mW(erp) = 4 dBm	critical

Table A.1.2: Analogue TV subjected to LTE mobile terminal

The table above summarizes the results for the scenario with a mobile terminal in the same room. It shows that the reception of DVB-C signals is already prevented by a mobile terminal transmitting at very low power, significantly lower than typical transmission powers of mobile phones currently in the market. As an example it might be considered that devices for the GSM900 band are built for peak transmission power of up to 2 W. This would be equal to about 100 times the transmission power that led to disturbances of DVB-C.

Setup 3 – Indoor, room next door	LTE transmitting power resulting in interference	
	3,0 m distance, through wall vertical	Reference value: 125 mW = 21 dBm
PAL reception	7,9 mW(erp) = 9 dBm	critical
DVB-C reception	32 mW(erp) = 15 dBm	critical

Table A.1.3: Analogue TV with interference source in neighbouring room

The table above shows a similar effect if the source of the interference is in the room next door. The 15 cm thick armoured (metal) concrete wall separating the two rooms was not sufficient to protect the DVB-C user in one room/apartment from the mobile transmission activities in the other room/apartment. This situation is particularly difficult to handle for broadcast service providers and network operators. It is almost impossible to determine the source of the disturbance of the picture, since it is depending on the usage of LTE services in the neighbourhood and lies outside the area of responsibility of the subscriber affected by the bad service.

As lab and field measurements have shown, there is interference created through direct transmission of mobile LTE terminals into terminal devices of the cable infrastructure. At the present time typical values for transmission power and antenna gain for mobile devices in the considered frequency range can not be exactly determined, yet. It is to be expected that the interference threshold of cable terminal devices is exceeded about 10-fold by the indoor uplink transmission. In some cases there might even by a 100-fold overrun for peak transmission power.

Based on these results, peak transmission power as well as average transmission power of mobile terminal devices has to be limited to ensure continued interference free operation of the cable infrastructure. From these results it can be assumed that not only TV sets and set-top boxes are affected, but also VCRs, DVRs, cable modems and embedded telephony adaptors (E-MTAs) and any devices equipped with conventional TV tuners and RF reception capabilities.

A.1.2 ANGA Presentation

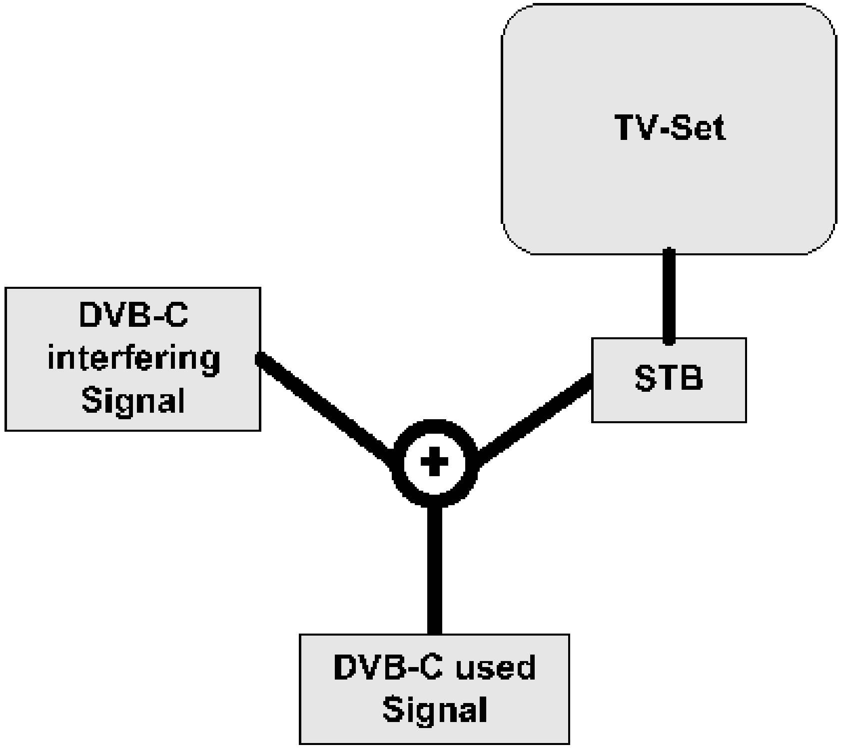
ANGA

Project Phases for testing the impact of LTE Transmission in the UHF frequency spectrum

Project ANGA / IRT
Dipl.-Ing. Carsten Engelke

ANGA

Phase I: Lab Experiment I



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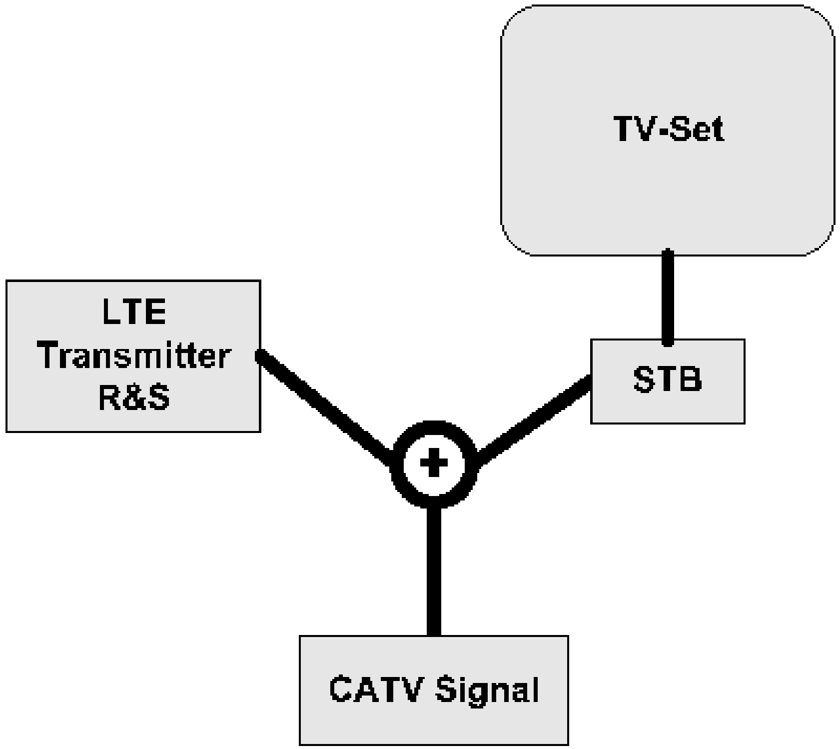
Phase I: Lab Experiment II



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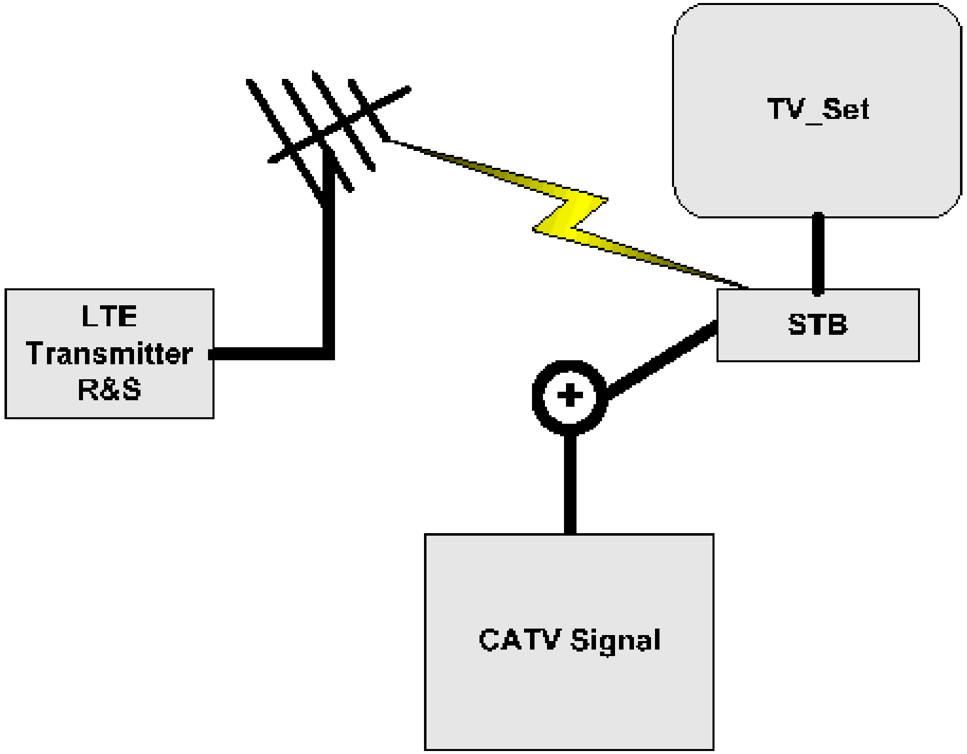
Phase I: Lab Experiment III



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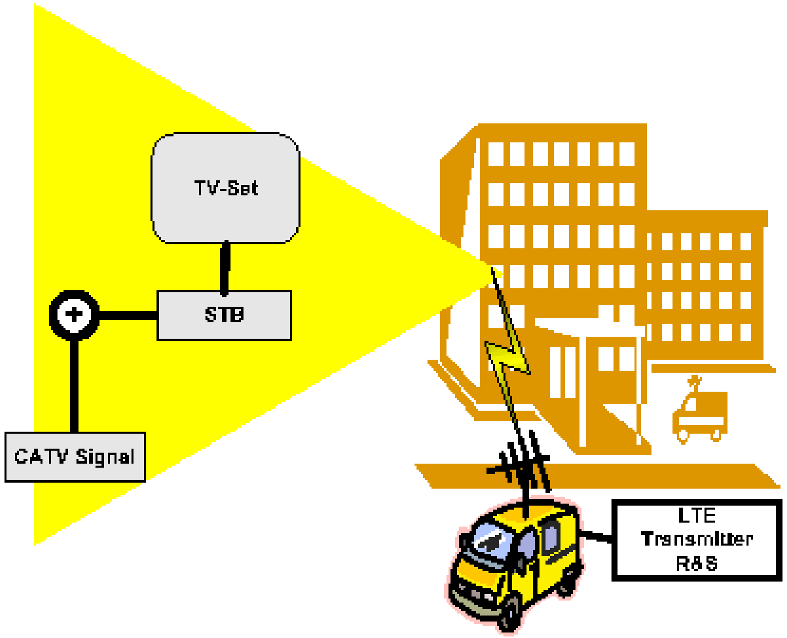
Project Phase II Field Measurement: Outdoor



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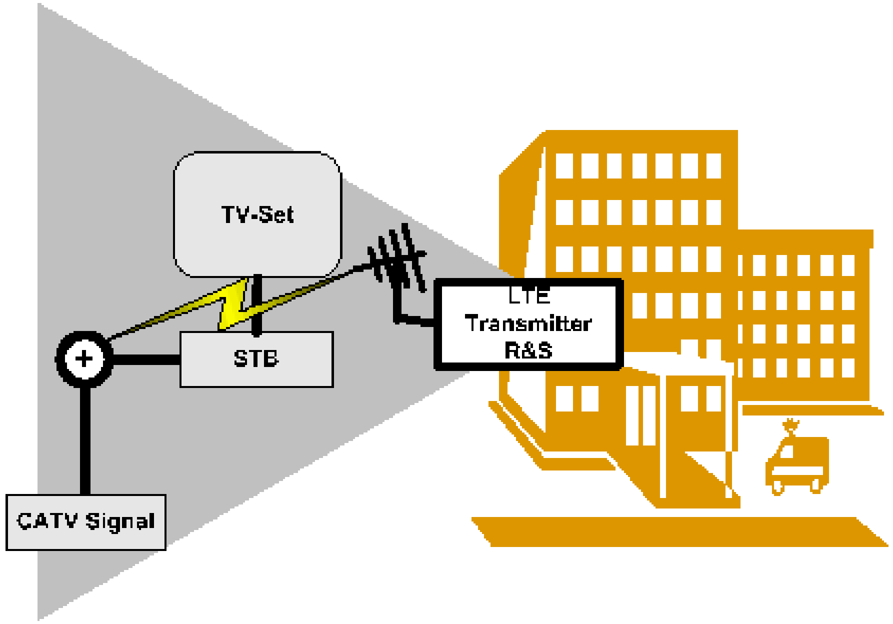
Project Phase II Field Measurement: Indoor



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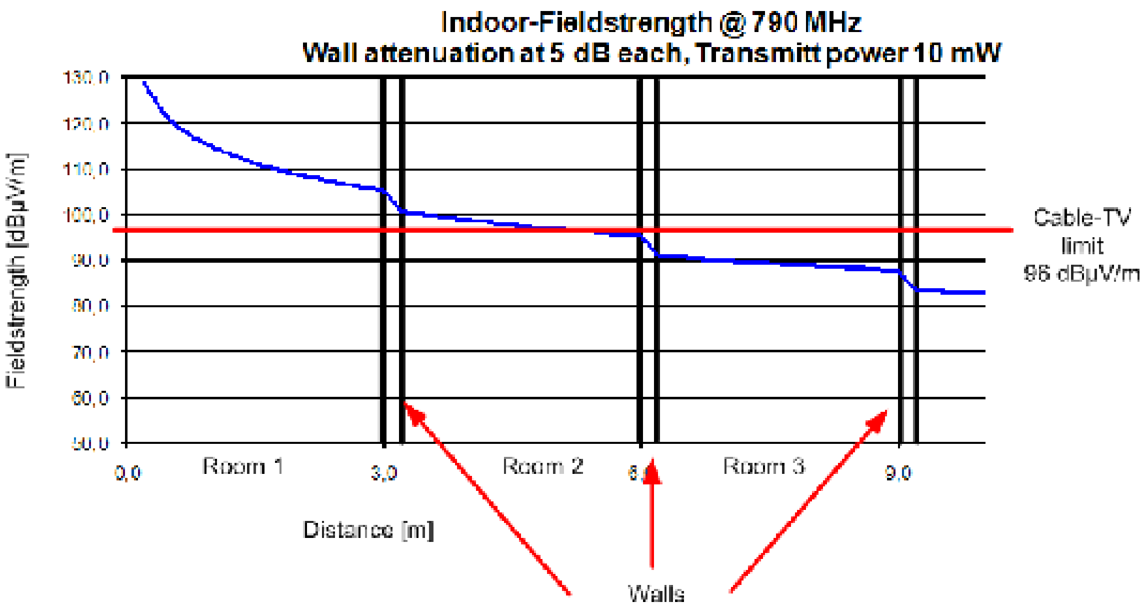
Project Phase III: Live Network (Outdoor)

Project Phase III: Live Network (Indoor)

Impact on DVB-C 64 QAM and analog services

ANGA

Result



Indoor-Fieldstrength @ 790 MHz
Wall attenuation at 5 dB each, Transmitt power 10 mW
130,0
120,0
110,0
100,0
90,0
80,0
70,0
60,0
50,0
Fieldstrength [dBµV/m]
0,0
Room 1
3,0
Room 2
Room 3
9,0
Distance [m]
Cable-TV
limit
96 dBµV/m
Walls

A.2 Austrian Measurements

A.2.1 Objective

To evaluate the impact to viewers of Cable Network (CATV) services from LTE mobile phone's operating within the same cable frequency band 790 MHz to 862 MHz. Potential interference from both WiMAX and UMTS services to CATV services is assessed.

A.2.2 Location

Klagenfurt, Austria with the test environment as given in Figure A.2.1. Tests were carried out in a typical room within a multi dwelling unit (MDU) through standard Cable Operator CATV installation, with a sample of 3 Set Top Boxes (STB's) from different manufacturers.

A.2.3 Test Setup

The testing was performed by local experts together with UPC-Austria and Rohde & Schwarz.

Both UMTS and WiMAX services were simulated within this band, with power levels adjustable from 1mW to 250mW at a distance varying between 1.5m and 15m from the STB.

The mobile phone signal was transmitted with the "Sendeantenne für UMTS und WiMAX" antenna. The log per antenna was used to measure the field strength.

Unscrambled DVB-C signals on 834 MHz (Channel 66) where fed in into the local Hub.

Outlet power level's where set according to the local Operators standards.

All tests were carried out with 64 QAM and 256 QAM input signal on the Set Top Box.

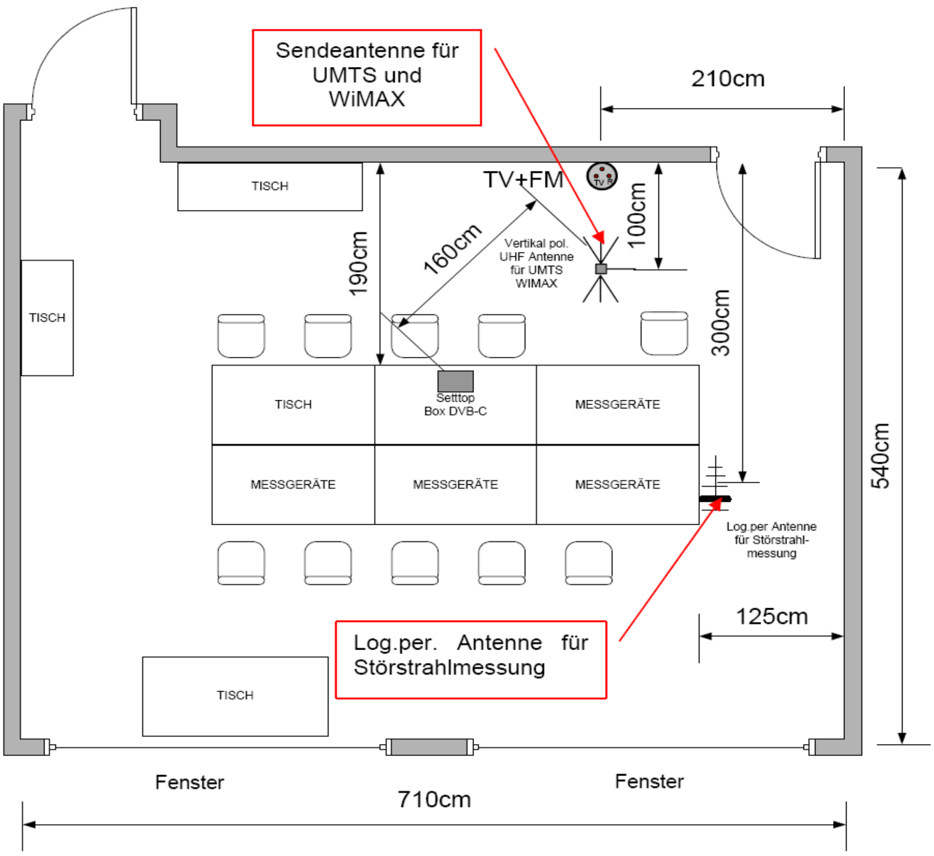


Figure 1: Test Configuration

A.2.4 Results

The influence of the transmissions on the measurement equipment was verified to eliminate any measurement errors.

All tests were done with 64 QAM and 256 QAM input signal on the Set Top Box.

The measurements for 64 QAM, disturbed with UMTS signals are as given in Table A.2.1

Belegung KTV:	**K66**	**Pegel Steckdose:**		**50 dBµV**	**Modulation:**	**64QAM**
SYMBOL RATE	**6.900 MSym/s**	**Datarate:**	38 Mbit/s	**Distanz Sendeantenne zu Steckdose:**		**1 m**

Messgerät		STB I Durchgang offen	STB I Durchgang 75 Ω Abschluss	STB II Durchgang offen	STB II Durchgang 75 Ω Abschluss	STB III Durchgang offen	STB III Durchgang 75 Ω Abschluss	Distanz STB zu Sende-antenne
Strahlungsleistung EiRP - UMTS (dBmW)	mW	Blocking im Bild	Blocking im Bild	Blocking im Bild	Blocking im Bild	Blocking im Bild	Blocking im Bild	
ohne		ok	ok	ok	ok	ok	ok	
0	1,00	ok	ok	ok	ok	ok	ok	
5	3,16	ok	ok	ok	ok	ok	ok	
6	3,98	ok	ok	ok	ok	ok	ok	
7	5,01	ok	ok	ok	ok	ok	ok	
8	6,31	ok	ok	ok	ok	ok	ok	
9	7,94	ok	ok	ok	ok	ok	ok	1,6 m
10	10,00	ok	ok	ok	ok	ok	slicing	
11	12,59	ok	ok	ok	ok	ok	slicing	
12	15,85	ok	ok	ok	ok	ok	fall of	
13	19,95	ok	ok	ok	freezing	ok		
14	25,12	ok	ok	ok	fall off	ok		
15	31,62	ok	ok	ok		slicing		
16	39,81	ok	fall off	ok		fall off		
17	50,12	slicing		ok				
18	63,10	fall off		fall off				

Table A.2.1

Measurements for 256 QAM, disturbed with UMTS signals are as given in Table A.2.2:

Belegung KTV:	**K66**	**Pegel Steckdose:**		**55,4 dBµV**	**Modulation:**	**256QAM**
SYMBOL RATE	**6.900 Msym/s**	**Datarate:**	52 Mbit/s	**Distanz Sendeantenne zu Steckdose**		**1 m**

Messgerät		STB I Durchgang offen	STB I Durchgang 75 Ω Abschluss	STB II Durchgang offen	STB II Durchgang 75 Ω Abschluss	STB III Durchgang offen	STB III Durchgang 75 Ω Abschluss	Distanz STB zu Sende-antenne
Strahlungsleistung EiRP - UMTS (dBmW)	mW	Blocking im Bild	Blocking im Bild	Blocking im Bild	Blocking im Bild	Blocking im Bild	Blocking im Bild	
ohne		ok	ok	ok	ok	ok	ok	
0	1,00	ok	ok	ok	ok	ok	ok	
5	3,16	ok	ok	ok	ok	ok	ok	
6	3,98	ok	ok	ok	ok	ok	ok	1,6 m
7	5,01	ok	ok	ok	ok	ok	slicing	
8	6,31	ok	ok	ok	ok	slicing	fall off	
9	7,94	slicing	ok	ok	fall off	slicing		
10	10,00	slicing	slicing	fall off		fall off		
11	12,59	fall off	fall off					
12	15,85							

Table A.2.2

A.2.5 Conclusion

Above 10 mW transmit power total outage at 1.5m and 15m for 250mW on DVB-C signals, high noise on analog TV channels.

Significant distortion from mobile phones operating on a DVB-C frequency (790 MHz – 862 MHz).

1/25 of the normal output power from an LTE mobile phone will interfere with the cable viewers TV service.

The interference affects at least 10% of available downstream capacity which badly impacts the broadband data and interactive services.