Performance challenges for LTE deployment in digital dividend in Croatia

Mr.sc. Alberto Teković

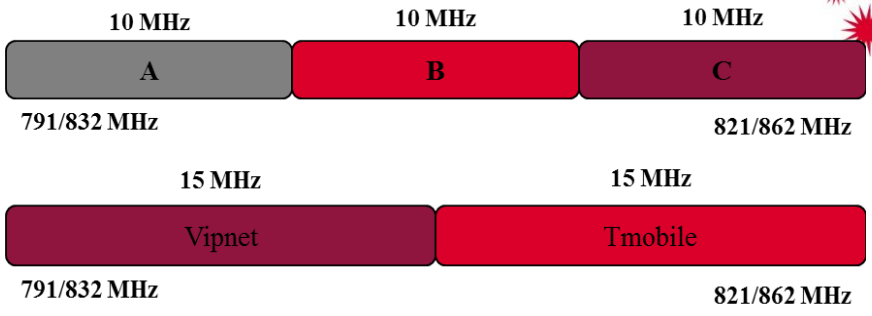
Thursday, 25 September 2014

Agenda

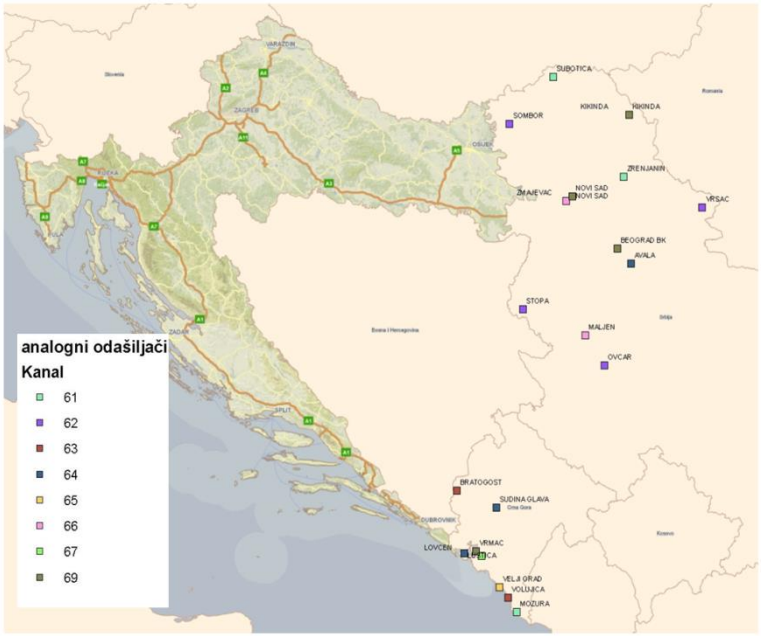
1. Introduction
2. Interference cases
    1. Digital TV (DVB-T) broadcasting in digital dividend
    2. LTE in digital dividend co-channeling with DVB-C system
    3. Analogue TV broadcasting in digital dividend
    4. LTE in digital dividend interfering DVB-T receivers
3. Conclusion

INTRODUCTION

- **Vipnet's frequency bands**
  - GSM (P-GSM, E-GSM)
  - UMTS (UMTS2100, UMTS900)
  - LTE
    - 1800 (10 MHz)
    - 800 (15 MHz)



kanal	21 55	56 60	61 69	70
frekvencija	470MHz	750MHz	790MHz	860MHz
usluga	DVB-T/-H	DVB-T	IMT	
MUX A - državni	4xSD: HRT1, HRT2, NOVA, RTL + 1xSD: slobodno			
MUX B - državni	5xSD: slobodno			
MUX C - državni	5xSD: slobodno			
MUX D - regionalni /državni	1-3xSD: regionalni postojeći + 2-4 SD: slobodno (regionalni/državni)			
MUX E - državni	DVB-H: slobodno ~30 TV programa ili ~ 60 radio programa			
MUX F - državni /regionalni	slobodno: DVB-T ili DVB-H			
MUX G - regionalni /državni	slobodno: DVB-T ili DVB-H			
MUX H - regionalni	slobodno: DVB-T ili DVB-H			



UHF frequency bands IV i V [1

ANALOGUE TV BROADCASTING IN DIGITAL DIVIDEND

- Republic of Bosnia and Herzegovina
- Republic of Serbia
- Republic of Montenegro

DIGITAL TV (DVB-T) BROADCASING IN DIGITAL DIVIDEND

- TV operators in Italy

LTE deployment IN DIGITAL DIVIDEND (Croatian case)

LTE in DIGITAL DIVIDEND CO-CHANNELING with DVB-C system

- Due to susceptible active\ passive elements

LTE in DIGITAL DIVIDEND interfering DVB-T receivers

- Adjacent bands
- Image frequency

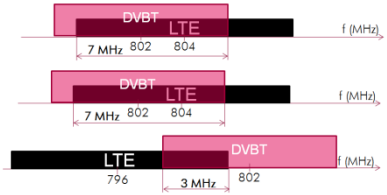
MEASUREMENT SETUP- overview

- **Scope :To measure an intersystem interference imapct from DVBT operating in digital dividend on LTE throughput performance in DL direction**

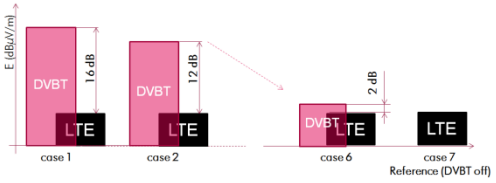
- **Test location\ equipment**
  - Žitnjak, Zagreb
  - DVBT transmitter temporarily installed on Vipnet's site
  - R&S TSMW scanner + ROMES (outcar antenna, 13dBi)
  - Huawei E392U + TEMS Investigation (UDP test)

- **Measurement points**
  - 4 measurement points:
    - M1- very good LTE radio conditions
    - M2 and M3 average LTE radio conditions
    - M4 poor radio conditions

- **Test cases**
  - 3 test cases:
    - T1- DVBT and LTE overlapped in DD 7MHz
    - T2- DVBT and LTE overlapped in DD 5MHz
    - T3- DVBT and LTE overlapped in DD 3MHz



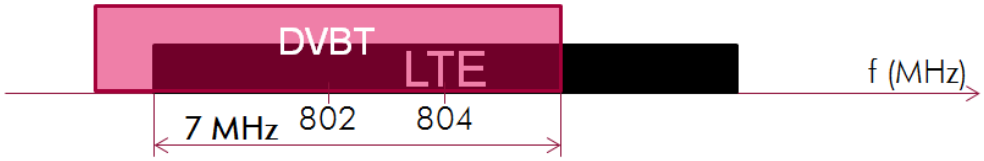
- **Ratio steps**
  - 7 ratio steps
  - Reference value when DVBT turned off

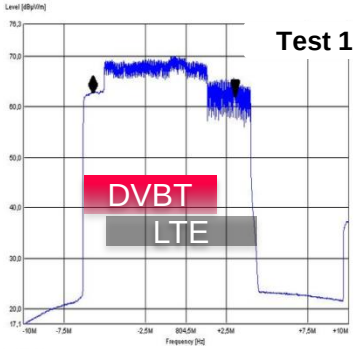


MEASUREMENT SETUP- measurement points

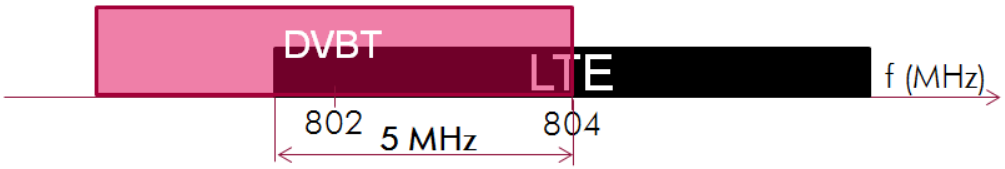
MEASUREMENT SETUP- test cases

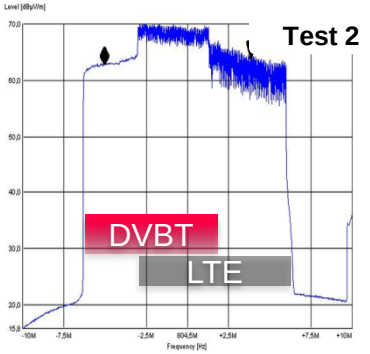
- **Test case 1 (7 MHz overlap)**
  - LTE800, UARFCN= 6280 (f= 804 MHz, bandwith 10MHz)
  - DVBT, channel 62 (f= 802 MHz, bandwith 8MHz)



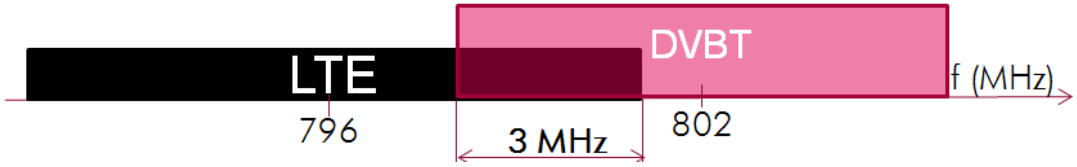


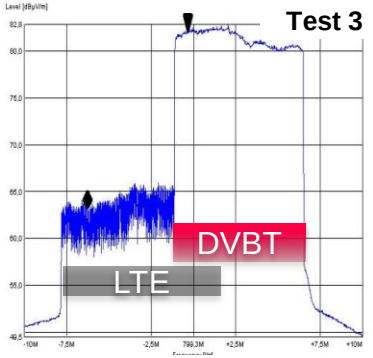
- **Test case 2 (5 MHz overlap)**
  - LTE800, UARFCN= 6300 (f= 806 MHz, bandwith 10MHz)
  - DVBT, channel 62 (f= 802 MHz, bandwith 8MHz)





- **Test case 3 (3 MHz overlap)**
  - LTE800, UARFCN= 6200 (f= 796 MHz, bandwith 10MHz)
  - DVBT, channel 62 (f= 802 MHz, bandwith 8MHz)





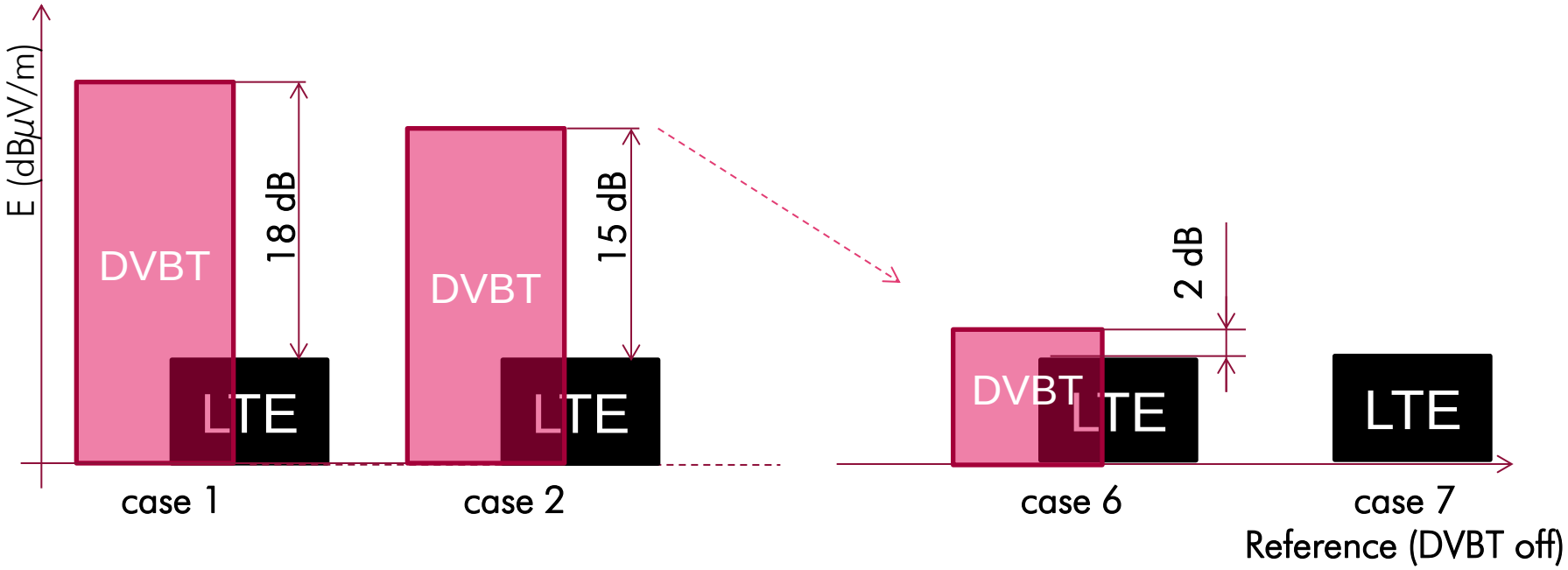
MEASUREMENT SETUP- ratio steps

LTE

> constant output power

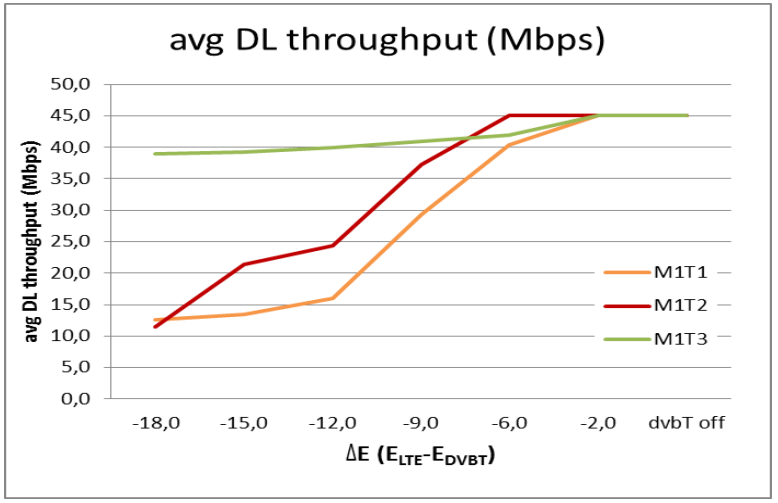
DVBT

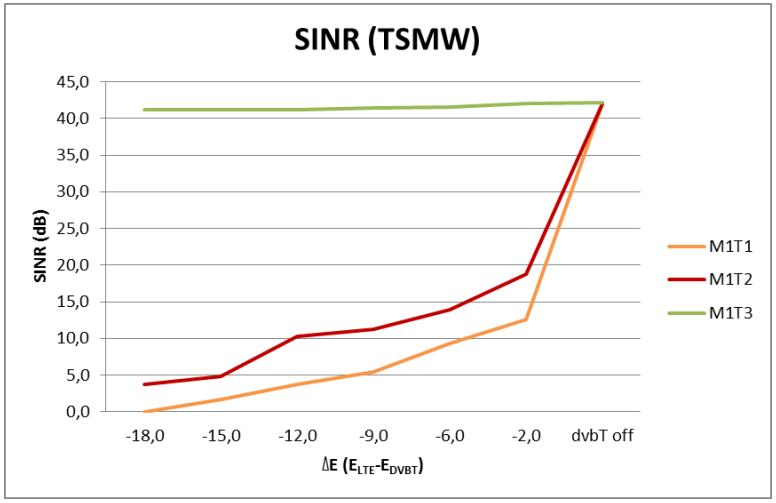
> attenuation increased following steps: 0, 3, 6, 9, 12, 15dB

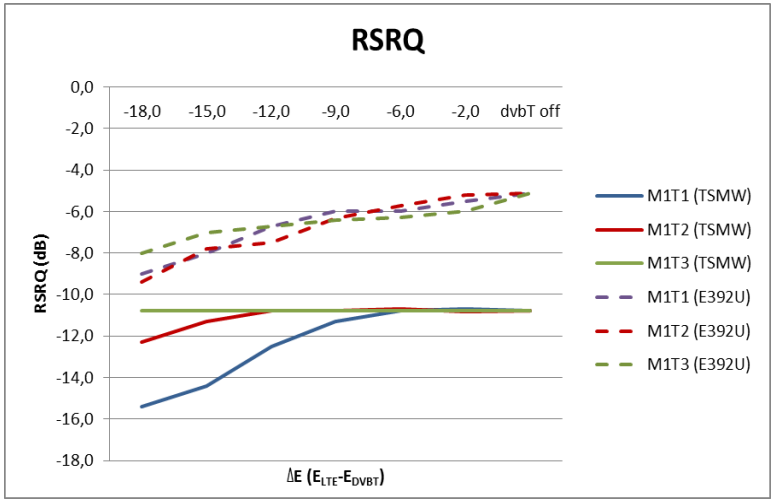


RESULTS- measurement point 1

M Point	LTE, E (dBµV/m)	DVBT, E (dBµV/m)	RSRP, TSMW (dBm)	RSRP, E392U (dBm)
M1	88,0	106,0	-55,0	-68,0
M2	80,5	97,5	-66,3	-92,7
M3	76,0	94,3	-70,0	-83,0
M4	63,5	81,4	-80,0	-100,0



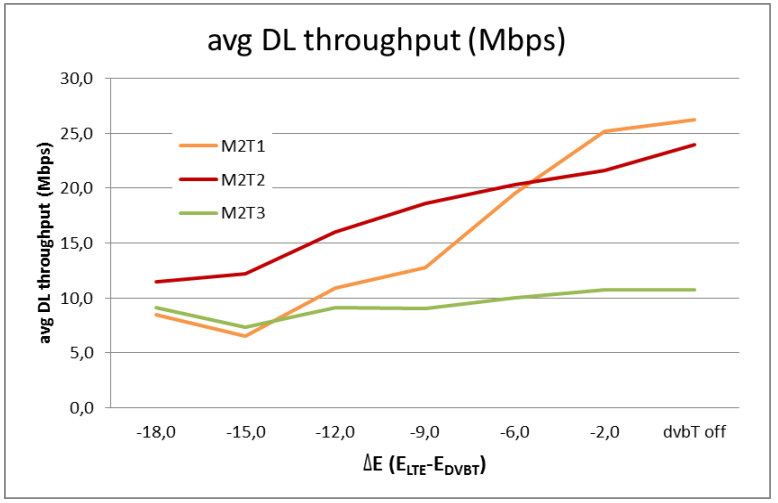


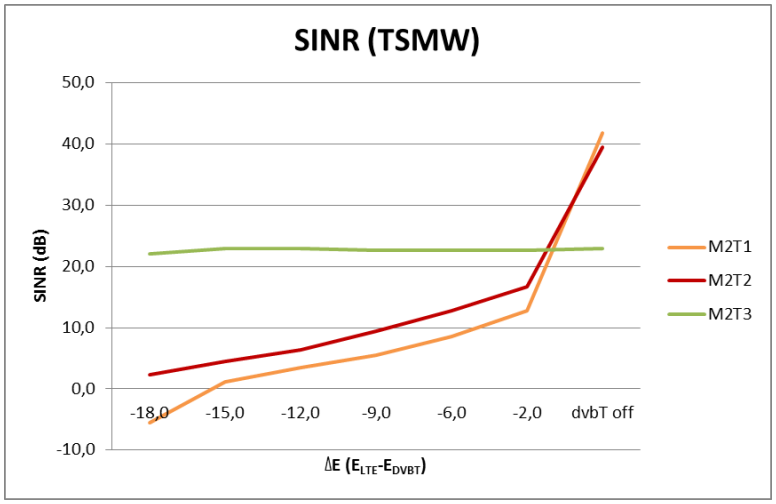


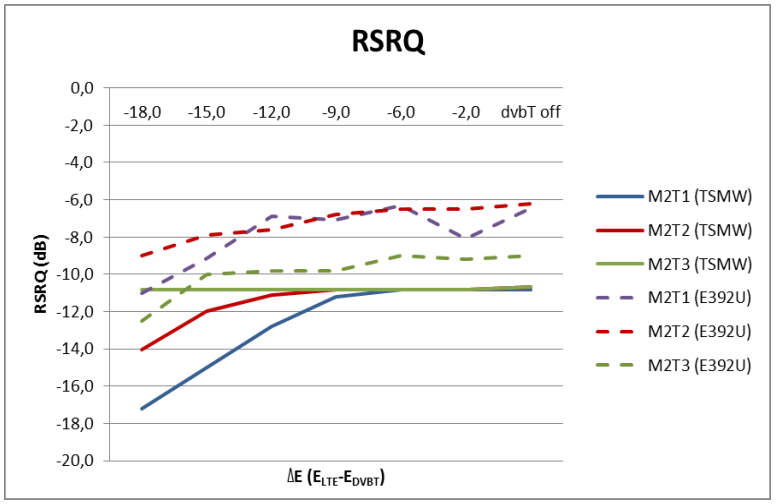
*T3 terminal issue, low performance on DL EARFCN 6200 detected
Different algorithm applied for RSRQ calculation in scanner and terminal

RESULTS- measurement point 2

M Point	LTE, E (dBµV/m)	DVBT, E (dBµV/m)	RSRP, TSMW (dBm)	RSRP, E392U (dBm)
M1	88,0	106,0	-55,0	-68,0
M2	80,5	97,5	-66,3	-92,7
M3	76,0	94,3	-70,0	-83,0
M4	63,5	81,4	-80,0	-100,0



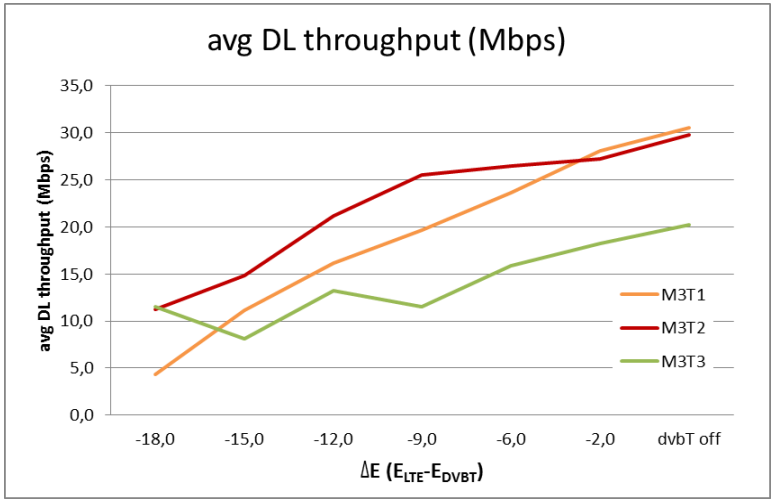


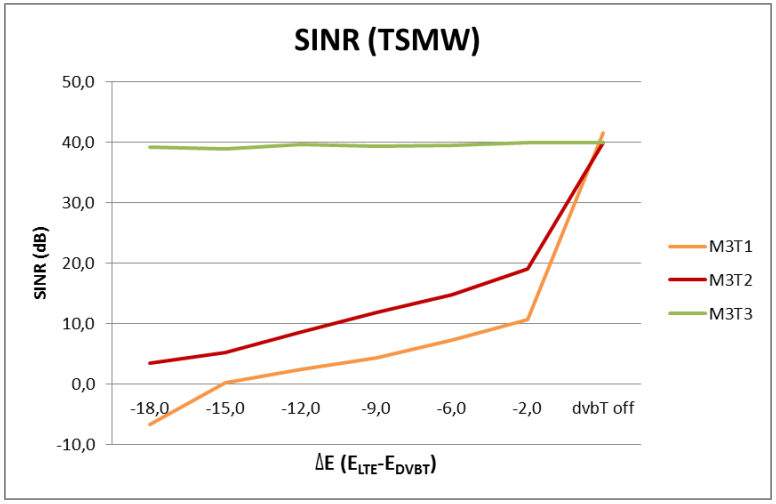


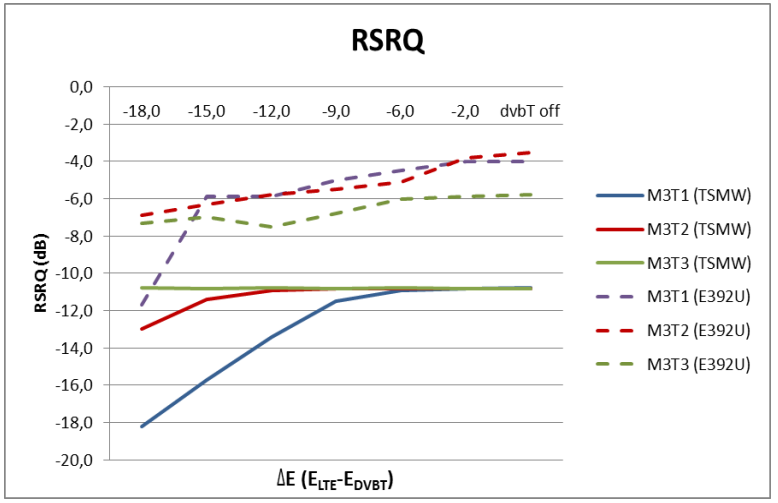
*T3 terminal issue, low performance on DL EARFCN 6200 detected
Different algorithm applied for RSRQ calculation in scanner and terminal

RESULTS- measurement point 3

M Point	LTE, E (dBµV/m)	DVBT, E (dBµV/m)	RSRP, TSMW (dBm)	RSRP, E392U (dBm)
M1	88,0	106,0	-55,0	-68,0
M2	80,5	97,5	-66,3	-92,7
M3	76,0	94,3	-70,0	-83,0
M4	63,5	81,4	-80,0	-100,0



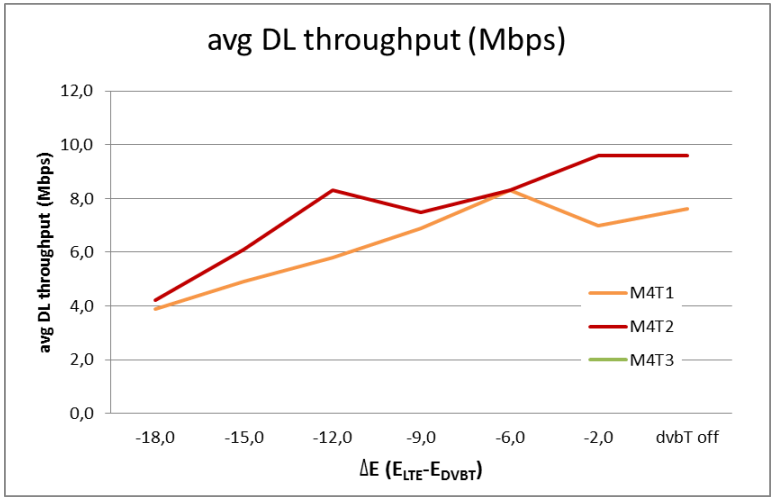


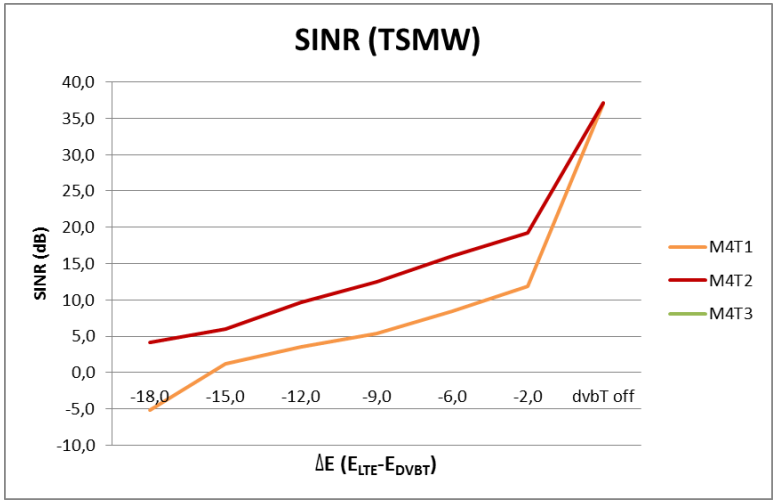


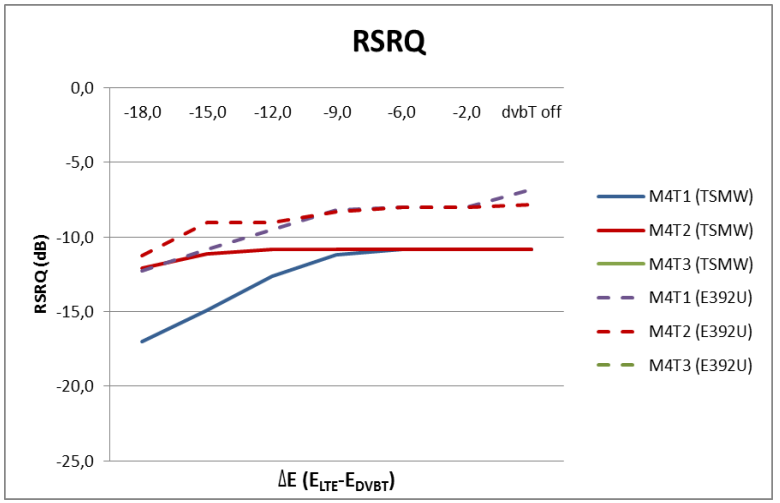
*T3 terminal issue, low performance on DL EARFCN 6200 detected
Different algorithm applied for RSRQ calculation in scanner and terminal

RESULTS- measurement point 4

M Point	LTE, E (dBµV/m)	DVBT, E (dBµV/m)	RSRP, TSMW (dBm)	RSRP, E392U (dBm)
M1	88,0	106,0	-55,0	-68,0
M2	80,5	97,5	-66,3	-92,7
M3	76,0	94,3	-70,0	-83,0
M4	63,5	81,4	-80,0	-100,0







*T3 terminal issue, low performance (no network attach for this case) on DL EARFCN 6200 detected
Different algorithm applied for RSRQ calculation in scanner and terminal

CONCLUSION

- Italy does not follow the GE06 broadcasting plan, and there is a big concern that they won't stich to agreement in digital dividend as well.

- **Measurement shows that an overlap between DVBT and LTE signal of 7MHz and 5 MHz causes strong degradation on LTE performance, visible to customer as a decreased download throughput (for some cases up to 78%)**

- For all mentioned reason, an acquisition of a digital dividend spectrum for LTE deployment without a detailed analysis of all mentioned intersystem interference scenarios would be risky and inconsiderate investment step for a mobile operator in Republic of Croatia.

- Responsible regulator will not announce tender for digital dividend spectrum, without of clear knowledge of all possible consequences. For all mentioned reasons, further researches in this area are necessary.

ANALOGUE TV BROADCASTING IN DIGITAL DIVIDEND

- Republic of Bosnia and Herzegovina
- Republic of Serbia
- Republic of Montenegro

DIGITAL TV (DVBT) BROADCASTING IN DIGITAL DIVIDEND

- TV operators in Italy

LTE deployment IN DIGITAL DIVIDEND (Croatian case)

LTE in DIGITAL DIVIDEND CO-CHANNELING with DVBC system

- Due to susceptible active\ passive elements

LTE in DIGITAL DIVIDEND interfering DVBT receivers

- Image frequency issue

AGENDA

1. Introduction
2. Co-channeling probability
3. Modulation and signal level variation
4. Error correction algorithm
5. Inhouse measurement
   - > Cables test
   - > Connectors/ other passive elements test
   - > STBs test
6. Policy and approach in other countries
7. Conclusion

INTRODUCTION

> LTE band operating in Digital Dividend in Europe defined as **Band 20** [0]

E-UTRA Operating Band	Uplink (UL) operating band BS receive UE transmit F_{UL_low} – F_{UL_high}	Downlink (DL) operating band BS transmit UE receive F_{DL_low} – F_{DL_high}	Duplex Mode
...			
17	704 MHz – 716 MHz	734 MHz – 746 MHz	FDD
18	815 MHz – 830 MHz	860 MHz – 875 MHz	FDD
19	830 MHz – 845 MHz	875 MHz – 890 MHz	FDD
20	832 MHz – 862 MHz	791 MHz – 821 MHz	
21	1447.9 MHz – 1462.9 MHz	1495.9 MHz – 1510.9 MHz	FDD
...			

> The top four channels of the cable band overlap the 6/ 3 LTE uplink channels (5MHz bandwidth case/ 10MHz case) on which mobile handsets transmits

Mobile Servic												
LTE Downlink Range 6 Channels à 5 MHz						Duplex gap 11 Mhz	LTE Uplink Range 6 Channels à 5 MHz					
791-796	796-801	801-805	805-811	811-816	816-821	821-832	832-837	837-842	842-847	847-852	852-857	857-862

Cable								
72 Mhz (9 Channels à 8 MHz)								
790-798	798-806	806-814	814-822	822-830	830-838	838-846	846-854	854-862

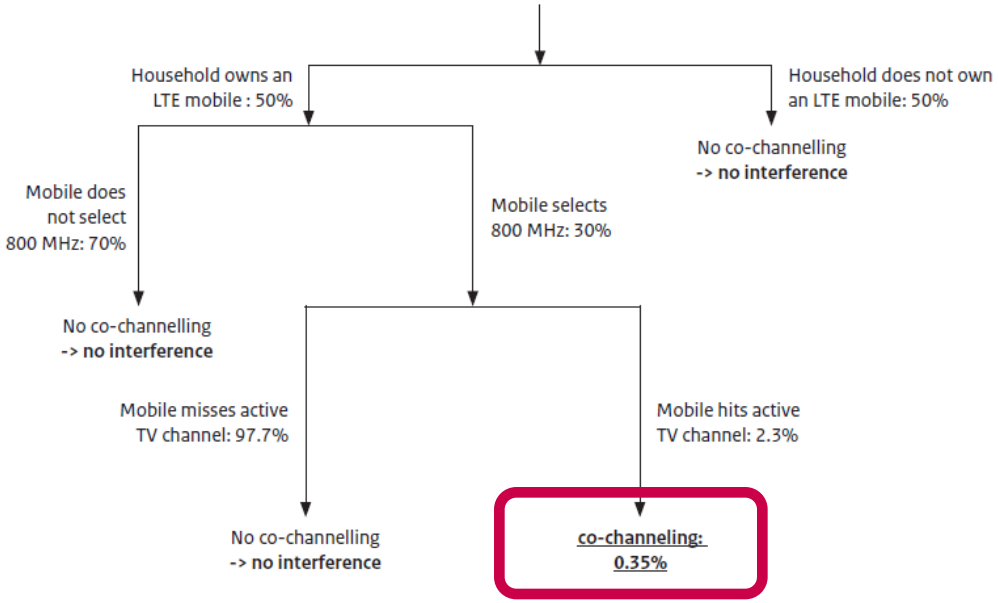
[0] 3GPP TS 36.101

CO-CHANELLING PROBABILITY

> **To what extent may interference be caused to inhome cable TV systems due to introduction of LTE applications in the Digital Dividend band of 790-862 MHz?**

> For the occurrence of these 'coinciding channels', the following three conditions must be met simultaneously [1]:

1. **somebody must actively be using an 800 MHz mobile handset, which**
2. **selects the same channel as**
3. **the channel to which the TV is tuned at that particular moment.**



[1] University of Twente „Analysis of interference to cable television due to mobile usage in the Digital Dividend, July 2010

CO-CHANELLING PROBABILITY

- Significant decrease in probability of experienced interference in case when basic package channels were not allocated to LTE spectrum channels, **by a magnitude of a factor of 10 or more [1]**
- **Different absolute figures for Croatian case, but if this method is used significant gain in decreasing probability should be expected**

Basic package channels allocated to LTE spectrum channels

Table 1: statistical probability of co-channelling under Scenario I: basic package channels arbitrarily allocated across TV frequency band

	A	B	C
Households with LTE mobile	50%	50%	90%
Probability of 800 MHz	30%	50%	10%
Probability of co-channeling	0.35%	0.59%	0.21%

Table 3: probability of actually experienced interference under Scenario I: basic package channels arbitrarily allocated across TV frequency band

	A	B	C
Probability of co-channeling	0.35%	0.59%	0.21%
Probability of interferentie	48%	48%	48%
Probability of experienced interference	0.17%	0.28%	0.10%

Basic package channels not allocated to LTE spectrum channels

Table 2: statistical probability of co-channelling under Scenario II: basic package channels not allocated to LTE spectrum channels

	A	B	C
Households with LTE mobile	50%	50%	90%
Households with plus package	20%	50%	20%
Percentage plus package viewing time	50%	50%	80%
Probability of 800 MHz	30%	50%	10%
Probability of co-channeling	0.035%	0.15%	0.034%

Table 4: probability of actually experienced interference under Scenario II: basic package channels not allocated to LTE spectrum channels

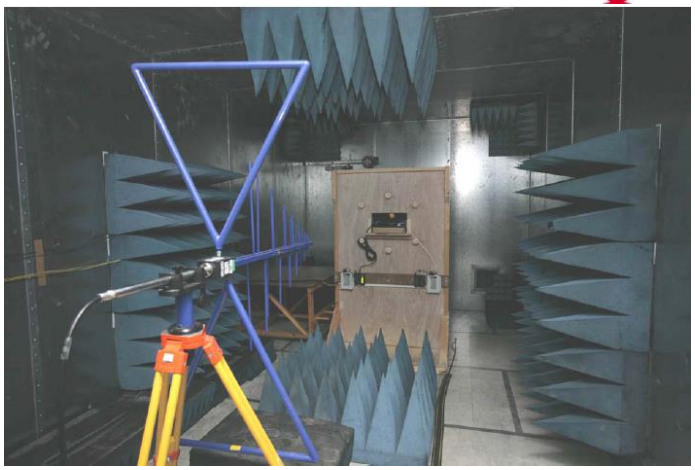
	A	B	C
Probability of co-channeling	0.035%	0.15%	0.034%
Probability of interferentie	48%	48%	48%
Probability of experienced interference	0.017%	0.070%	0.016%

[1] University of Twente „Analysis of interference to cable television due to mobile usage in the Digital Dividend, July 2010

MODULATION AND SIGNAL LEVEL VARIATION

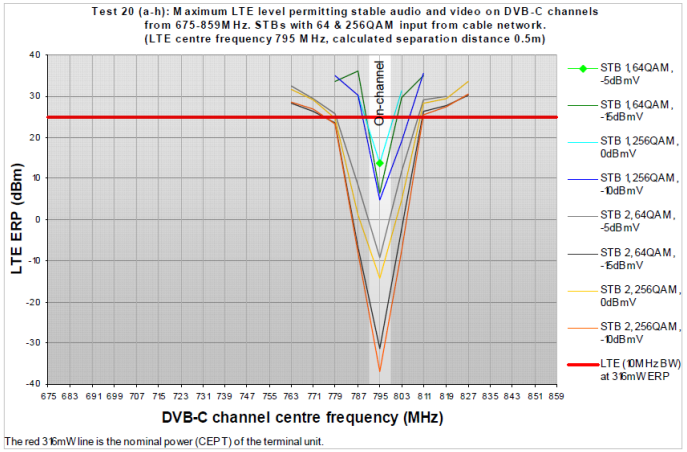
SETUP

- Test system configured to analyze the impact of modulation and signal level variations
- The LTE interferer, a 10MHz bandwidth (FDD) uplink signal, was radiated at the EUT at 795MHz while the STB was tuned throughout the band



RESULT

- **A regression to a more robust form of modulation 64QAM from 256QAM provides a marginal (between approximately 0 and 5.4dB) improvement in immunity [3].**
- **More beneficial is a 10dB increase in input power level, reflecting a change in real-world scenarios from 'acceptable' to 'excellent' input level (improvement of between approximately 7.2 and 22.7dB) [4].**
- The input level of the wanted signal is critical to the good or otherwise performance of the CPE device. In order to operate effectively, DVB-C 64QAM signals require a signal-to-noise ratio of 30dB or better, and 256QAM of 35dB or better..



Graph 1: LTE-radiated STBs 1 & 2 with a variety of supplied modulations and input levels

[3] Implications of the digital dividend proposals, Cable Europe Labs testing programme, CEL-DD02-SUM-S(QAM) V1.0 (11-02-2010)
[4] ANGA/IRT Study on Interference from Bidirectional Mobile Services into Cable TV Infrastructures

ERROR CORRECTION ALGORITHM

- Forward-Error Correction (FEC) technology is used within DVB-C transmissions to correct errors, and they are usually able to operate effectively **when the signal-to-noise ratio is a few dB too low**.

- These are shown in many set top box diagnostic screens as a ‘Pre-RS error’ figure, which is the number of errors present in the transport stream before the Reed-Solomon (the name of the FEC device) filter.

- Where the errors can be corrected, the ‘Post-RS errors’ figure remains zero. Where either the quantity of errors is too great or an error is unrecoverable (both of which can be caused by a signal level that is too low),a ‘Post RS error’ is displayed, and is usually accompanied by a visual or audio manifestation of the error, usually taking the form of macroblocking [5]

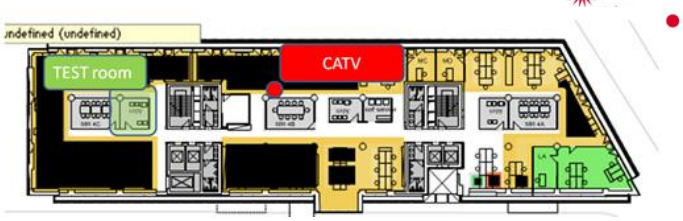
- **Cable operators should take into account to implement FEC algorithm, in order to compensate decreased interference immunity of the system caused from modulation upgrade**

[5] Implications of the digital dividend proposals, Cable Europe Labs testing programme, Set Top Boxes (STB), Draft CEL-DD02-SUM-S(QAM) V1.0 (11-12-2009)

INHOUSE MEASUREMENT- test setup

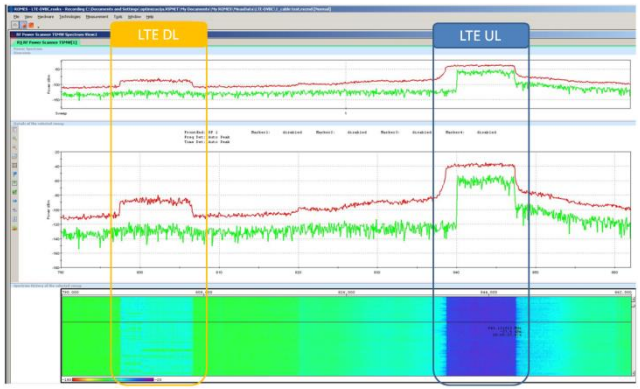
LOCATION

- High distance between CATV connection point and TEST room, in order to isolate interference only to the test equipment part

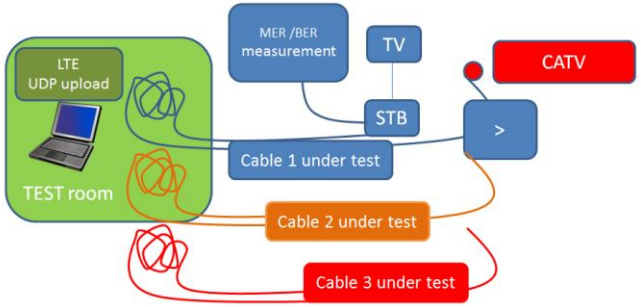


SIGNAL

- **CATV**, measurement conducted for three different signal levels:
  - 53 dBµV, Low signal level
  - **60 dBµV, Typical signal level present in cable home installations**
  - 65 dBµV, Maximum allowed input signal level for an STB



- **LTE**, interfering signal generated from an active UDP data upload using USB data stick (Huawei, E392U), with following parameters
  - EARFCN DL 6260 (fc=802MHz), UL 24260 (fc=843 MHz)
  - UeTxPwr=20dBm (not the maximum value, $UeTxPwr_{max}$=23dBm ±2 dB)
  - From USB data stick: RSRP=-83 dBm\ RSRQ= -6 dB
  - Form scanner: PWR_{UL}=-41dBm\ PWR_{DL}=-94dBm (at the test point)



EQUIPMENT\ DEVICE UNDER TEST

- Passive and active elements, typically used in cable network shave been tested in order to define critical interference susceptible points:
  - cables, connectors, splitters, other passive elements, STBs

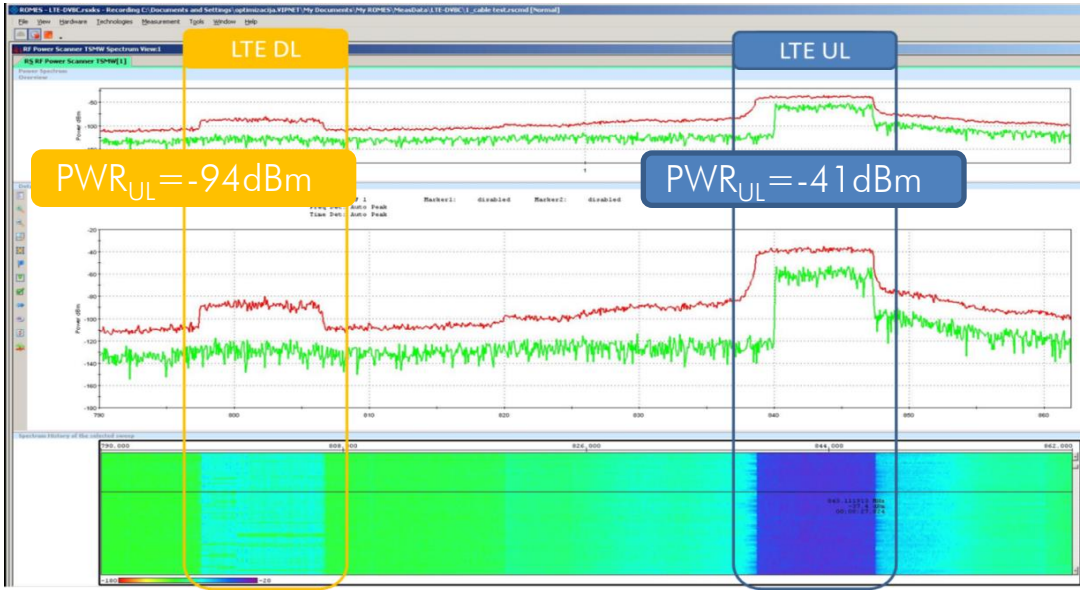
INHOUSE MEASUREMENT- test setup

What is critical, uplink or downlink?

> typical expected indoor ownlink LTE signal level to be expected around -80 to -100 dBm or less. In this measurement case, LTE antenna has been situated on the roof of the building, and the measurement has been conducted 3 floors bellow. PWR_{DL}=-94 dBm has been measured

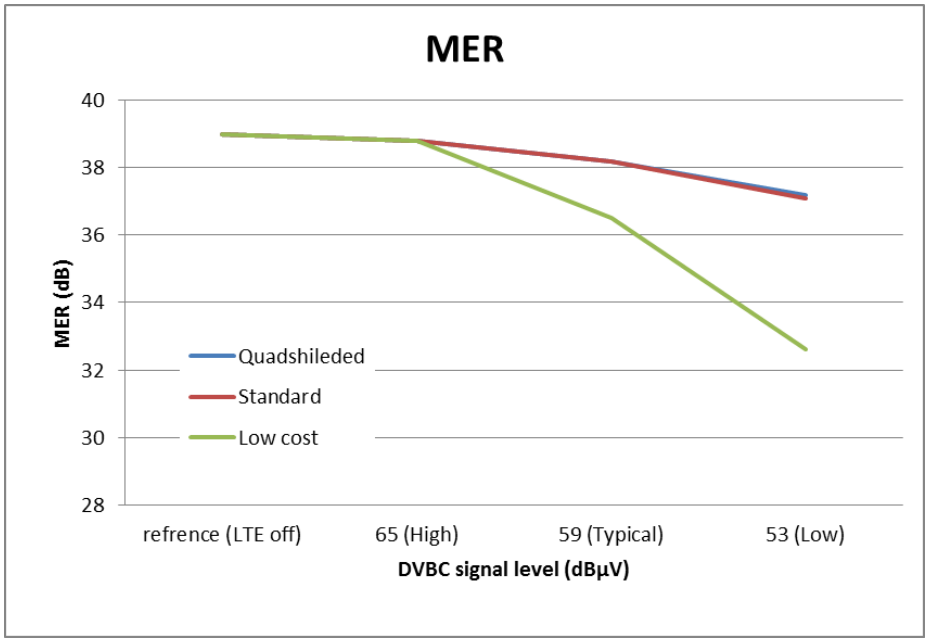
> at a distance of 1m between LTE USB data stick (active UDP data upload), transmitting with 20dBm, scanner has measured PWR_{UL}=-41 dBm

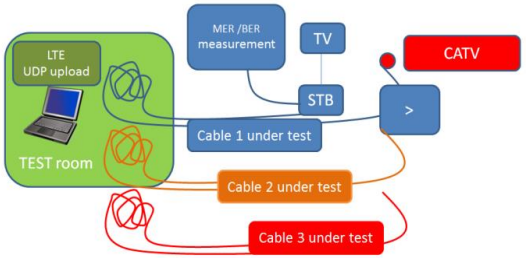
> **Therefore, we can conclude that LTE uplink is critical DVBC co-channeling generator**

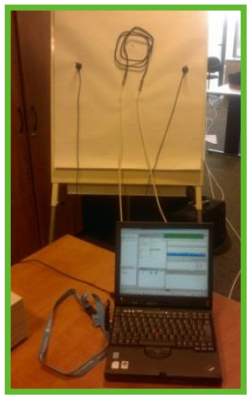


INHOUSE MEASUREMENT- cable test

- Three different cables have been tested
  - **CABLE1** quad shielded cable (green on the photo) that Bnet uses it in their head ends
  - **CABLE 2** standard cable (white on the photo) used for inhome installation by Bnet and their subcontractors
  - **CABLE 3 0,5m low cost cable (black on the photo) provided with STB box (only cable tested, original connectors have been replaced with the FF connection) is the only cable with significant interference susceptibility**

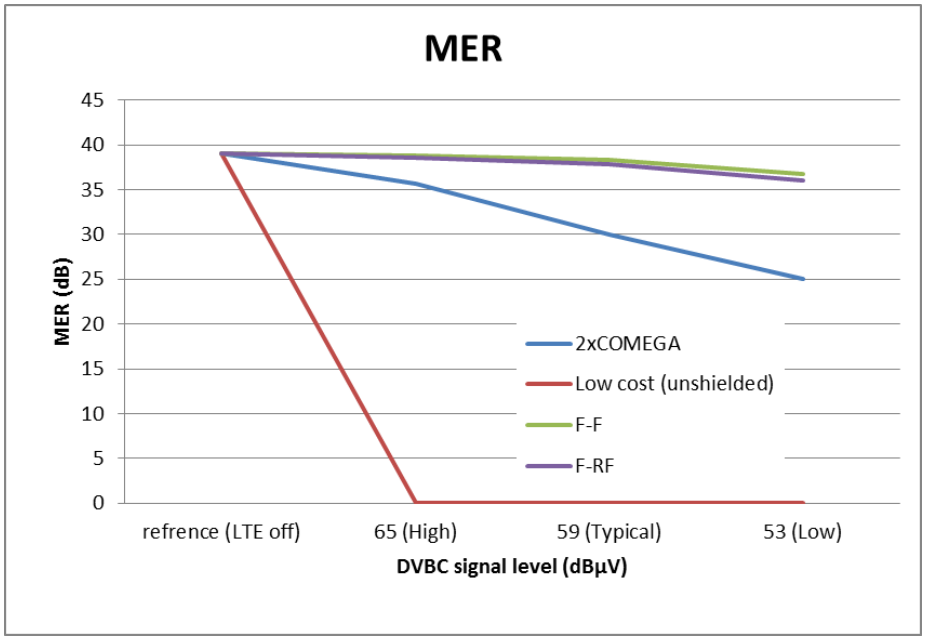


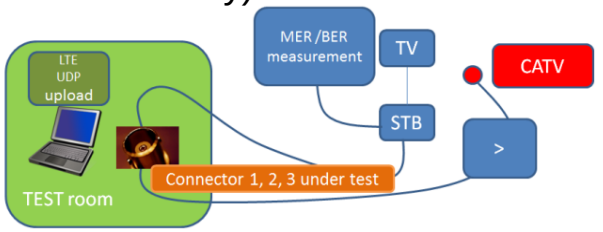




INHOUSE MEASUREMENT- connectors test

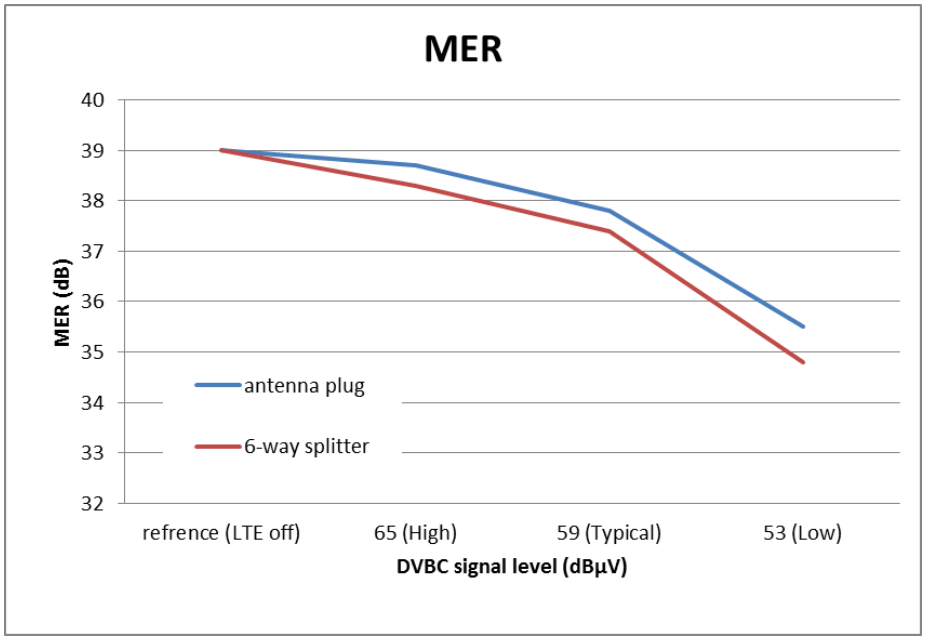
- Four connectors configurations have been tested
  - **2xCOMEGA** mainly used by cable companies for cable to STB connection
  - **COMEGA-Low cost (unshielded) Unshielded connectors are critical, and shouldn't be used at all!**
  - **F-F** mainly used for installation purposes (very good interference immunity)
  - **F-RF** sometimes used for installation purposes

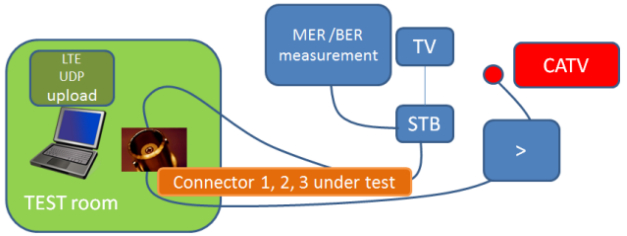


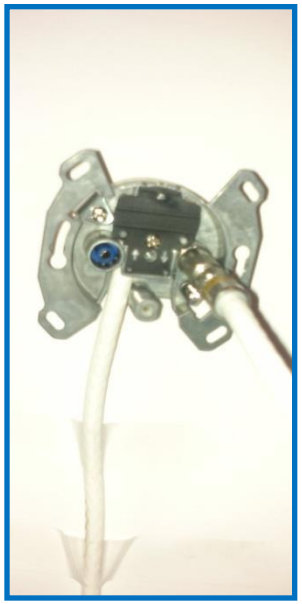


INHOUSE MEASUREMENT- other passive elements

- Additional passive elements used in cable TV home installations have been tested
  - **ANTENNA PLUG** used in all Inhome installations
  - **6-WAY SPLITTER** for inhome\ inbuilding installation



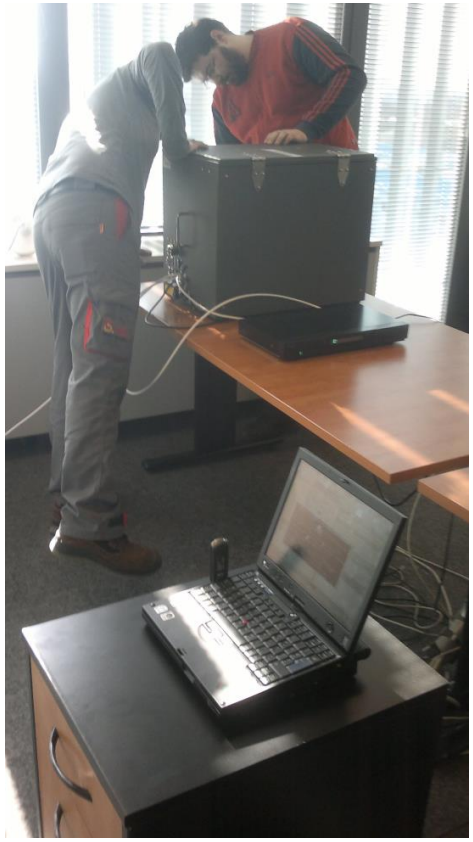


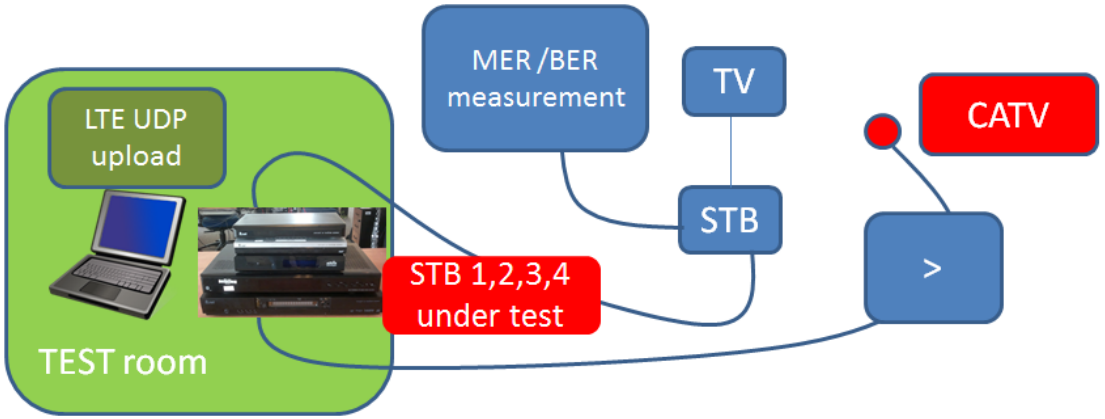


INHOUSE MEASUREMENT- STB on test

Different STB has been tested:

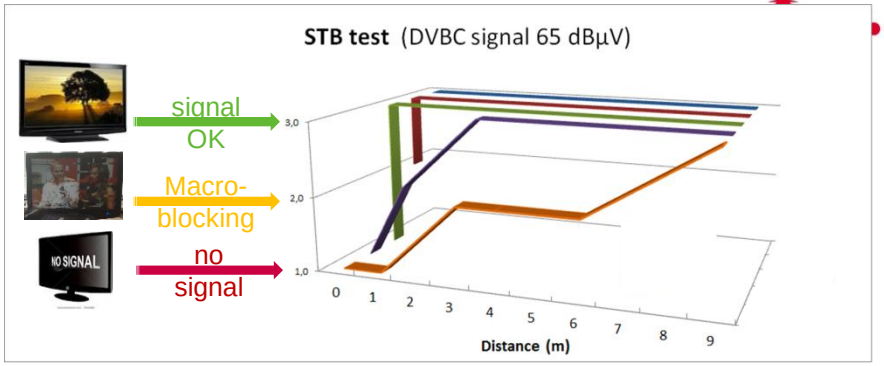
- 3 STB units in use in croatian networks: purple, orange and red
- 1 units currently under test and considered to be used in croatian cable network**:** green
- 1 unit (the most robust one) not used and currently not considered to be used: blue

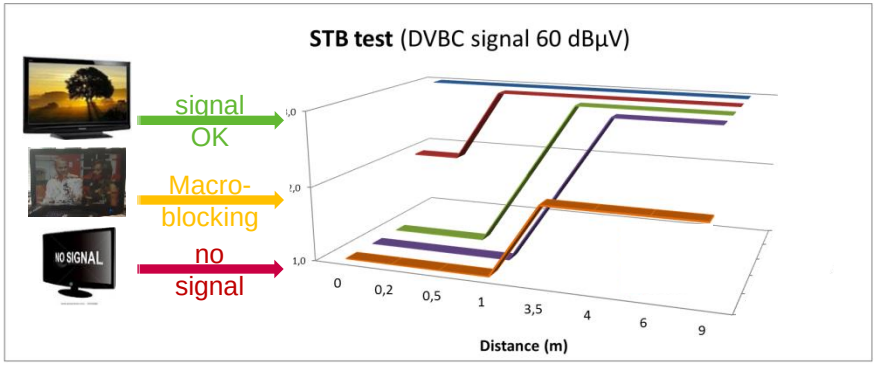


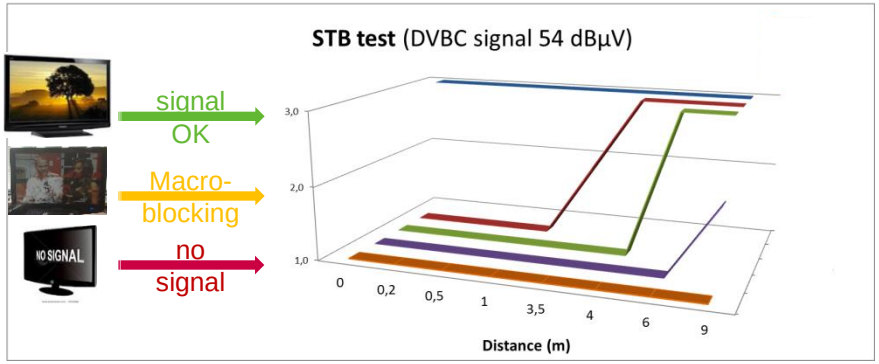


INHOUSE MEASUREMENT- STB on test

- **BLUE STB,** the only unit fully immune to co-channel interference from LTE UL (for every tested case)
- **RED STB,** the second best unit on the test. Performing well in case of typical (60 dBµV) DVBC input signal level, or better (65 dBµV) . Not that good in case of low input signal level.
- **GREEN STB,** the best of the „small housing" units, but still susceptible to co-channeling. In case of typical DVBC input signal, the macroblocking is visible for every distance between LTE and STB minor than 3,5m.
- **PURPLE AND ORANGE STB,** both units very susceptible to interference. In case of a typical DVBC input signal, purple unit performing good only for distance between LTE and STB 4m or higher. For the same typical DVBC input signal case, orange unit has a macroblocking issue up to distance of 9m.







POLICY AND APPROACH IN OTHER COUNTRIES [1]

To get an impression of the awareness and potential measures, nine European administrators answered the questionnaire [2] (Belgium, Estonia, Finland, Hungary, Ireland, Slovakia, Czech Republic, Sweden and Switzerland). The results show a diverse picture. The results, based on these countries, are as follows:

1. Only 4 countries expect problems related to interference. The other countries have a low cable density or the relevant frequencies are not in use for cable.
2. Switzerland is the only country that conducted its own research, and the results are publically available.
3. Switzerland analyzed the scope of the problem and concluded that the problem is not as serious as expected (at any arbitrary point in time there is a 90% probability of less than 23 interference incidents. At a point in time at which on an average evening many people are watching TV, the number of simultaneous interference incidents in Switzerland is approximately 17). For this reason, no general limitations will be imposed on the rollout of LTE.
4. **In terms of precautionary measures, the most frequently cited measures are improved cabling inside the home, and TVs and set-top boxes with improved immunity. One country is considering reduced LTE power levels. Three countries are proposing not to use the relevant channels on cable**
5. **Only 1 country indicated that it has legal means to impose precautionary measures on cable, the others explicitly indicated that radio services have priority.**
6. In most countries it is impossible to hold one specific stakeholder generally responsible for interference incidents: depending on the segment of the system that fails, the responsible party could be the cable company, the mobile operator, TV viewer, mobile telephone user, or the equipment's manufacturer.
7. In line with previous, the party that will solve the issue in actual practice depends on the situation, but in general the approach used will involve the viewer and the cable company, and as a last resort will the authorities become involved.
8. In 5 of the 9 countries, an administrator is involved in one way or another in solving this type of interference incident.
9. **The principle point identified was that cable distribution is not a radio service and therefore does not have a legal right to protection.**

[1] University of Twente „Analysis of interference to cable television due to mobile usage in the Digital Dividend, July 2010
[2] ECC, Questionnaire on Cable TV receivers affected by New Radio services in the 800 MHz Ditigal Dividend band, Working group RA,Helsinki, 26 March 2010.

CONCLUSION

CO-CHANNELING PROBABILITY

> Significant decrease in probability of experienced interference in case when basic package channels were not allocated to LTE spectrum channels, according to some probability calculation by a magnitude of a factor of 10 or more.

MODULATION AND INPUT SIGNAL LEVEL

> A regression to a more robust form of modulation from 256QAM to 64QAM provides a marginal improvement in immunity.

> Increase in DVBC input power level is more beneficial.

ERROR CORRECTION ALGORITHM

> Cable operators should take into account to implement FEC algorithm, in order to compensate decreased interference immunity of the system caused from modulation upgrade

EQUIPMENT

> Better cables and plugs in the home in about half of the cases in which a consumer (cable operator) implements this measure, it solves the problem. To increase the immunity of the cables, it is also possible to install an amplifier.

> Inhouse measurements showed that all equipment is more or less susceptible to interference. The critical elements are: low cost cable provided with STB package, unshielded low cost connectors, and STB as the most susceptible part

OTHERS COUNTRY POLICY AND REGULATORY APPROACH:

> In terms of precautionary measures, the most frequently cited measures are improved cabling inside the home, and TVs and set-top boxes with improved immunity.

> The principle point identified was that cable distribution is not a radio service and therefore does not have a legal right to protection.

LTE deployment IN DIGITAL DIVIDEND (Croatian case)

ANALOGUE TV BROADCASTING IN DIGITAL DIVIDEND

- Republic of Bosnia and Herzegovina
- Republic of Serbia
- Republic of Montenegro

DIGITAL TV (DVBT) BROADCASTING IN DIGITAL DIVIDEND

- TV operators in Italy

LTE in DIGITAL DIVIDEND CO-CHANNELING with DVBC system

- Due to susceptible active\ passive elements

LTE in DIGITAL DIVIDEND interfering DVBT receivers

- Image frequency issue

INTRODUCTION

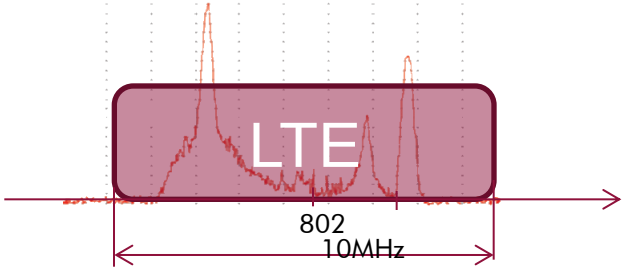
- **Performance challenges for LTE deployment in digital dividend in Croatia**
  - **ANALOG TV BROADCASTING IN DIGITAL DIVIDEND**
    - **Bosnia and Herzegovina**
      - slow transition from analogue to digital broadcasting, with no clearly defined deadline
    - **Republic of Serbia**
      - initial plan was to switch to digital broadcasting on 01.04.2012. Deadline was recently changed (02.03.2012.), and government decided to allow slow transition from analogue to digital broadcasting, with 2015. as a deadline (according to GE06, and not taking into account EU recommendation)
    - **Republic of Montenegro**
      - according to the information from „Strategija prelaska sa analognih na digitalne radio-difuzne sisteme u Crnoj gori" document, transition deadline is the end of 2012. According to some non authorized sources, there is a big chance for a deadline postpone.
    - **Hungary**
      - Currently working in simulcast

MEASUREMENT SETUP- overview

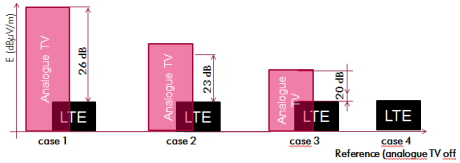
- **Scope :To measure an intersystem interference imapct from analogue TV operating in digital dividend on LTE throughput performance in DL direction**

- **Test location\ equipment**
  - Žitnjak, Zagreb
  - Analogue TV transmitter temporarily installed on Vipnet's site
  - R&S TSMW scanner + ROMES (outcar antenna, 13dBi)
  - Huawei E392U + TEMS Investigation (UDP test)

- **Measurement points**
  - 1 measurement points:
    - M1- very good LTE radio conditions
    - M2- average LTE radio conditions



- **Test cases**
  - 3 test cases:
    - T1- analogue TV and LTE overlapped in DD 7MHz (audio)
    - T2- analogue TV and LTE overlapped in DD 10MHz (video+ audio)
    - T3- analogue TV and LTE overlapped in DD 7MHz (video)

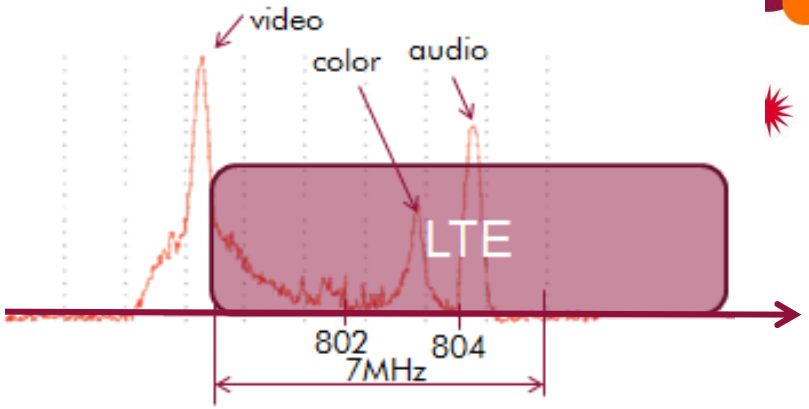


- **Ratio steps**
  - 3 ratio steps for M1, and 2 ratio steps for M2
  - Reference value when analogue TV broadcasting turned off

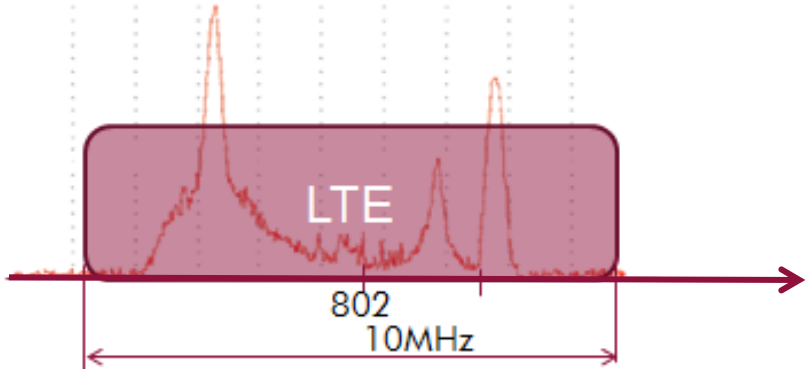
MEASUREMENT SETUP- measurement points

MEASUREMENT SETUP- test cases

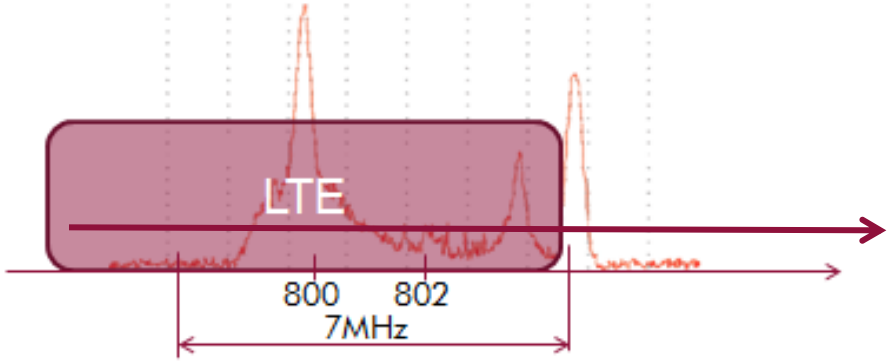
- **Test case 1 (7 MHz overlap, audio)**
  - LTE800, EARFCN= 6280
    (f= 804 MHz, bandwith 10MHz)
  - analogue, channel 62
    (f= 802 MHz, bandwith 8MHz)



- **Test case 2 (10 MHz overlap, video+ audio)**
  - LTE800, EARFCN= 6260
    (f= 802 MHz, bandwith 10MHz)
  - analogue, channel 62
    (f= 802 MHz, bandwith 8MHz)

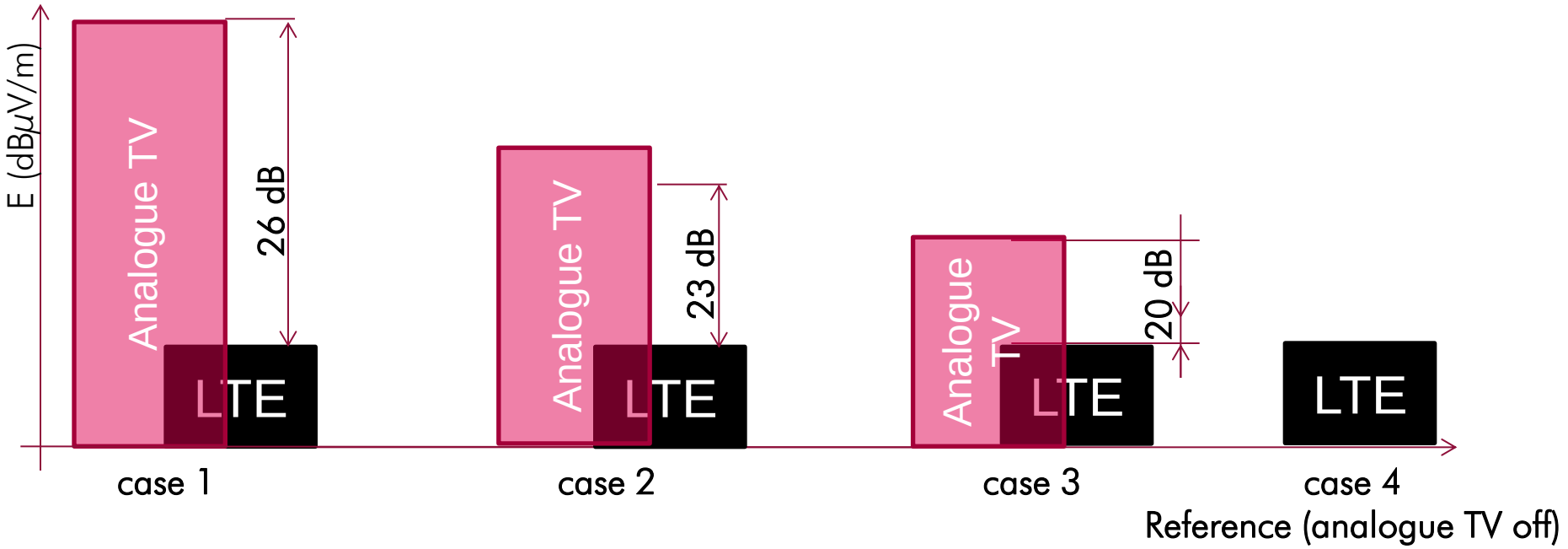


- **Test case 3 (7 MHz overlap, video)**
  - LTE800, EARFCN= 6240
    (f= 800 MHz, bandwith 10MHz)
  - analogue, channel 62
    (f= 802 MHz, bandwith 8MHz)



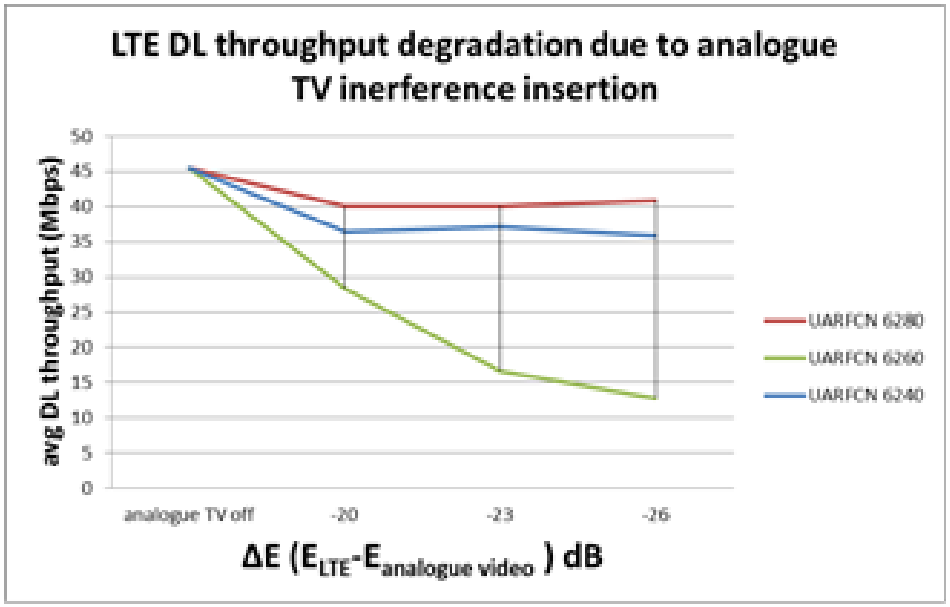
MEASUREMENT SETUP- ratio steps at measurement point 1

- **LTE**
  - constant output power
- **analogue**
  - 97 dbµV/m, than, attenuation increased in 3 steps
  - attenuation increased following steps: 0, 3, 6dB



RESULTS AND CONCLUSION

- Worst case when video and audio overlap LTE. Performance (throughput) degradation on the downlink up to 65%
- For partial LTE signal overlap (audio or video from analogue TV), performance degradation between 10- 20%
- Best case, only audio overlaps LTE signal



LTE deployment IN DIGITAL DIVIDEND (Croatian case)

ANALOGUE TV BROADCASTING IN DIGITAL DIVIDEND

- Republic of Bosnia and Herzegovina
- Republic of Serbia
- Republic of Montenegro

DIGITAL TV (DVB-T) BROADCASING IN DIGITAL DIVIDEND

- TV operators in Italy

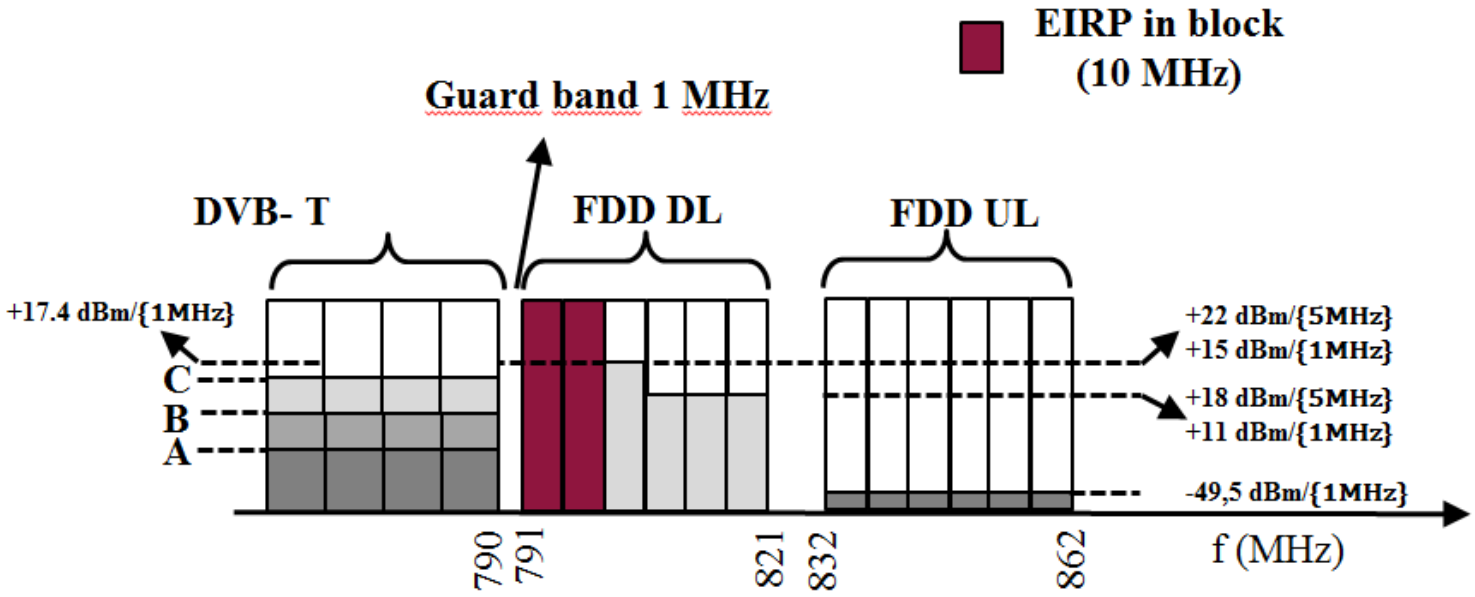
LTE in DIGITAL DIVIDEND CO-CHANNELING with DVBC system

- Due to susceptible active\ passive elements

LTE in DIGITAL DIVIDEND interfering DVB-T receivers

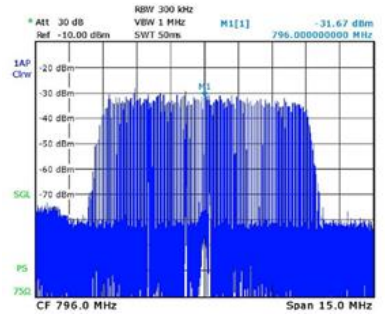
- Adfjacent channel
- Image frequency issue

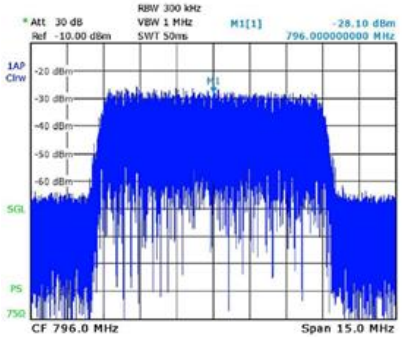
INTRODUCTION



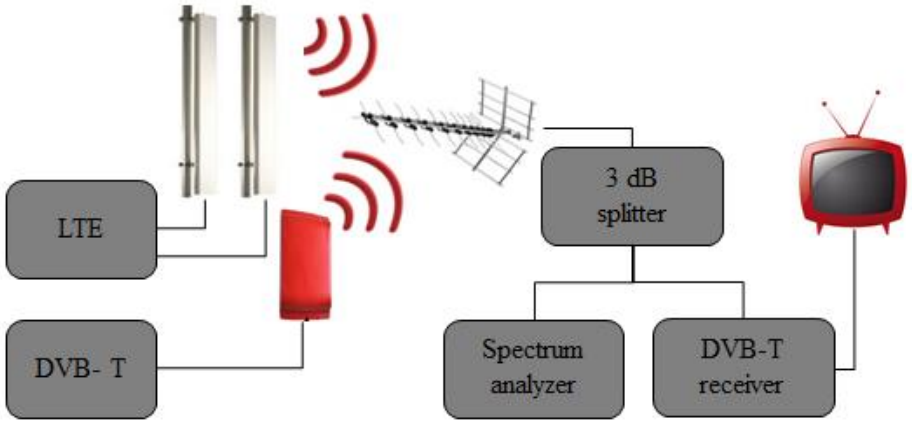
MEASUREMENT- scope and overview

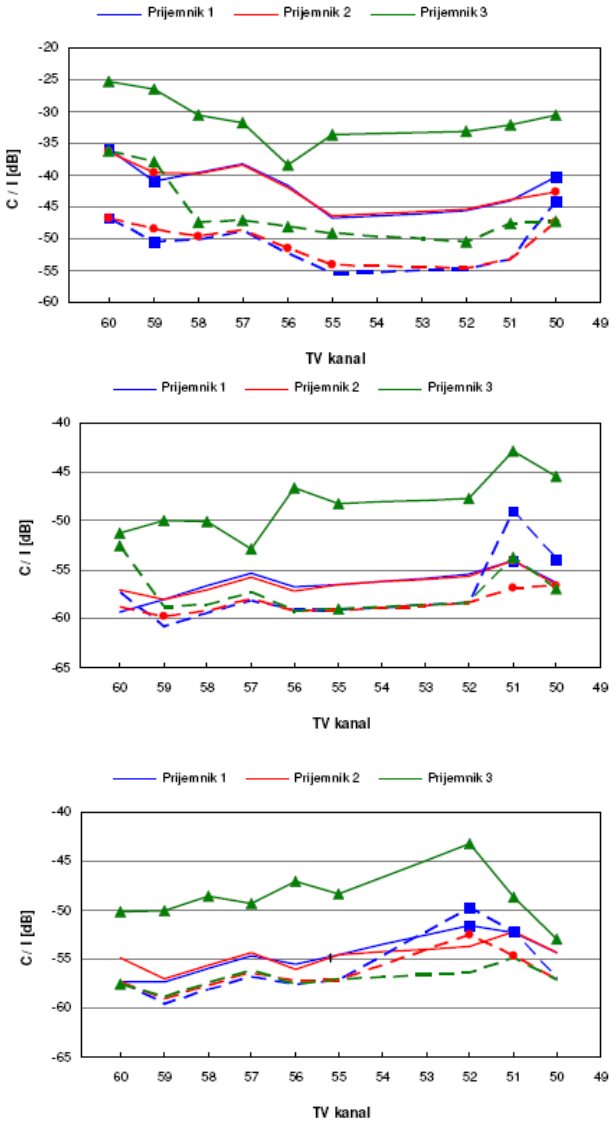
- **Scope :To define protection ratio between good DVB- T signal and interfering LTE signal operating in Digital Dividend**
- **Test equipment**
  - DVB-T transmitter (R&S SFE 100), levels: -50 and -70 dBm
  - **L**TE base station (RBS 6601 E///, 2x20W) operating in 3 bands: A: 791 ÷ 801, B: 801 ÷ 811, C: 811 ÷ 821 MHz
  - 3 DVB-T receivers on test: Nytro Box (NB-4001T), Strong SRT 8100 HD, Not Only TV- Scart DVB-T REC
  - LTE/ DVB-T signal measured using signal analyzer with following parameters: Span = 15 MHz, RBW = 100 kHz, VBW = 1 MHz
- **Test cases**
  - Two LTE operational modes: idle and full download (ftp DL service)
  - test cases :
    - **Home antenna system without amplifier (Gauss, Rice, Rayleigh channel)**
    - **Home antenna system with an amplifier**
    - DVB-T receivers interference sucscption
    - Indoor active antenna interfered from the LTE UL (ftp UL)





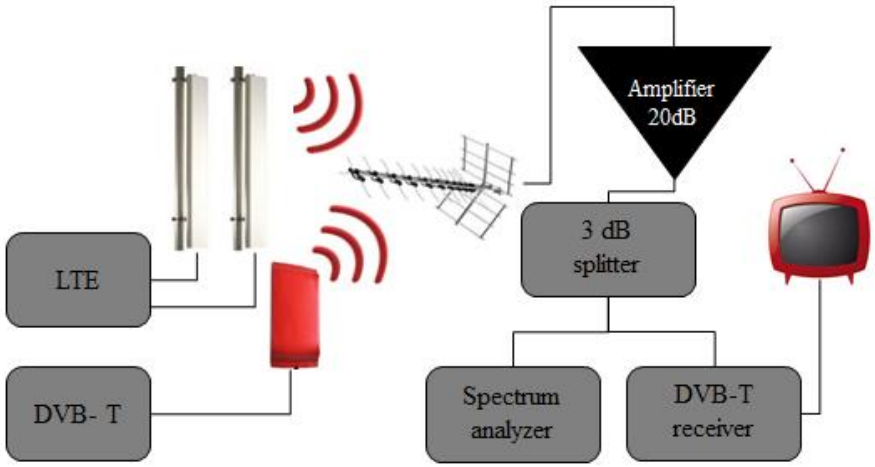
TEST RESULTS: Home antenna system without amplifier

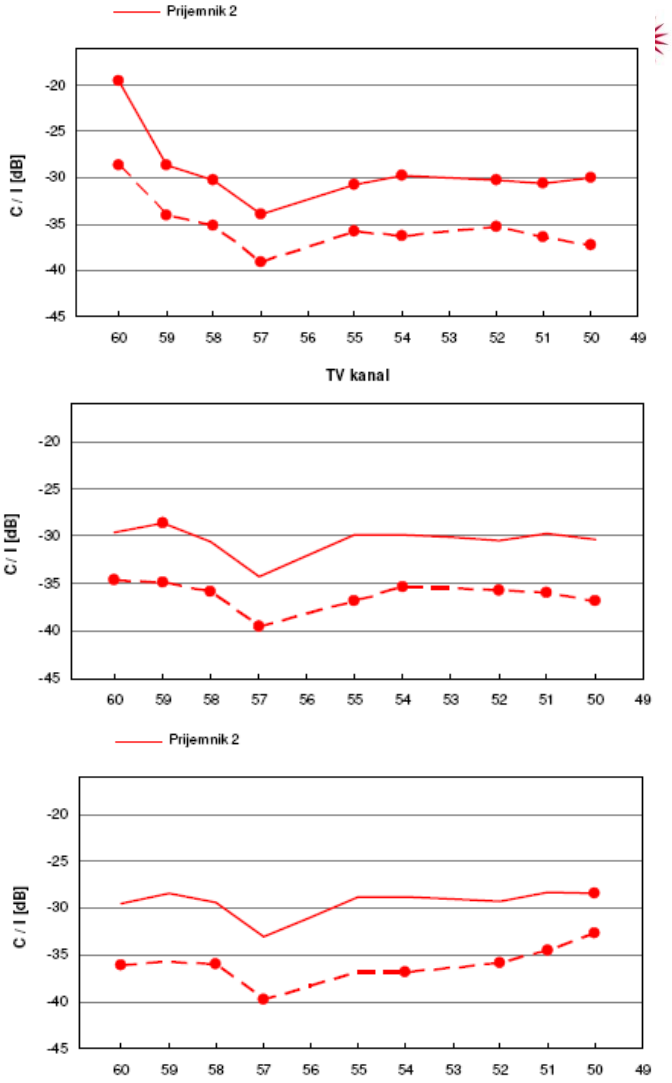




> **Test results from the LTE in bands A, B and C and DVB-T at -70dBm**

TEST RESULTS: Home antenna system with an amplifier





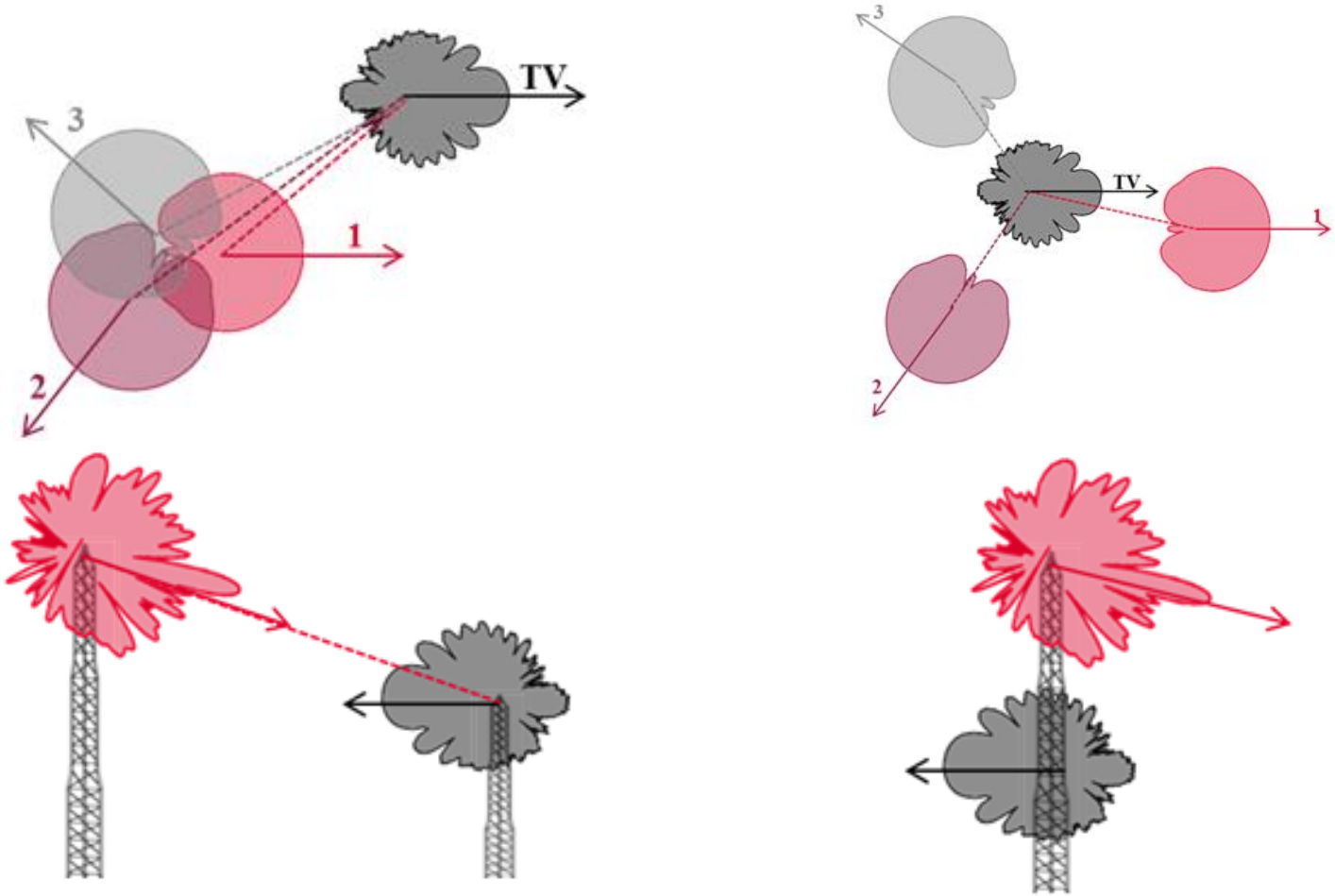
INTERFERENCE AVOIDANCE TECHNIQUES

- Interference avoidance techniques are described in CEPT reports 21, 22, 23 and 30 and can be summarized to:
  - **Reposition of the LTE/DVB-T antenna in vertical or horizontal direction**
  - Use of adaptive antennas
  - **Use of low band pass filters**
  - Use of orthogonal polarization
  - Output power adoption
  - LTE frequency planning

http://www.erodocdb.dk/docs/doc98/official/pdf/CEPTRep021.pdf
http://www.erodocdb.dk/docs/doc98/official/pdf/CEPTRep022.pdf
http://www.erodocdb.dk/docs/doc98/official/pdf/CEPTRep023.pdf
http://www.erodocdb.dk/docs/doc98/official/pdf/CEPTRep030.pdf

INTERFERENCE AVOIDANCE TECHNIQUES

> Reposition of the LTE/ DVB-T antenna in vertical or horizontal direction



INTERFERENCE AVOIDANCE TECHNIQUES

> Use of low band pass filters

DVB- T signal strength					85 dBµV/m	
DVB- T signal at DVB-T receiver point (G_a = 10 dB)					-40 dBm	
LTE Output Power					2 x 20 W	
LTE antenna Gain					15,8 dBi	
Polarization Loss					3 dB	
Additional attenuation [dB]	0	10	20	30	40	50
Protection ratio, *C/I* [dB]	Minimal distance between LTE antenna system and DVB-T antenna in order to assure interruption [m]					
-20	844	267	84	27	8	3
-25	474	150	47	15	5	2
-30	267	84	27	8	3	1
-35	150	47	15	5	2	0
-40	84	27	8	3	1	0
-45	47	15	5	2	0	0
-50	27	8	3	1	0	0
-55	15	5	2	0	0	0
-60	8	3	1	0	0	0