

UHF TV band spectrum and field-strength measurements before and after analogue switch-off

P. I. Lazaridis, S. Kasampalis, Z. D. Zaharis, J. Cosmas, A. Bizopoulos, P. Latkoski, L. Gavrilovska, O. Fratu, and R. Prasad.

Abstract— Measurements of UHF-TV band spectra and field-strength levels in the pre- and post-analogue switch-off periods in the cities of Thessaloniki and Skopje clearly demonstrate the much reduced spectrum occupancy, the lower signal levels, and the feasibility of digital dividend allocations to cellular operators in the 800 MHz band, as well as the feasibility of opportunistic secondary spectrum utilization in extensive parts of the spectrum. The risk of LTE-4G interference to TV services and vice-versa is also pointed out and clearly observed from spectrum measurements near a cellular base station.

Keywords—Analogue Switch-Off; ASO; Digital Switch Over; DSO; DTV; DVB-T; DVB-T2; GSM; Interference; LTE; SFN; Spectrum measurements; UHF TV Band; 4G; 800 MHz band

I. INTRODUCTION

The radio-frequency spectrum is a limited natural resource with great economic and social impact. Most countries around the world have already abandoned the traditional analogue broadcasting of TV signals in favor of the digital broadcasting techniques. In Europe DVB-T and DVB-T2 are used with great success and most European countries have already concluded the Analogue Switch-off (ASO). The modulation and coding gains of DTV combined with the compression gains of MPEG-4 type of video compression algorithms result in a significantly reduced spectrum usage and to higher transmitting bit rates (maximum 31.67 Mbits/s with 64QAM and DVB-T and 50.32 Mbits/s with 256QAM and DVB-T2). Furthermore, the principle of SFN (Single Frequency Network) broadcasting, where a single frequency channel is used in a whole geographical region or allotment, leads to even more efficient spectrum utilization. Moreover, digital receivers are much more sensitive than the analogue ones, requiring less than 25-30 dB μ V input, in the absence of reflections, for a blocking-free picture, while, on the contrary, analogue receivers needed at least 50 dB μ V input for snow-free reception. Consequently, lower field-strengths and lower transmitter powers are in generally required for the same geographical coverage.

P. I. Lazaridis and A. Bizopoulos are with Alexander Technological Educational Institute of Thessaloniki, 57400, Sindos, Greece. (email: pavloslazaridis@hotmail.com). S. Kasampalis and J. Cosmas are with the School of Engineering and Design, Brunel University, London UB8 3PH, U.K. Z. D. Zaharis, C. Skeberis and T. D. Xenos are with Aristotle University of Thessaloniki, Thessaloniki 54124, Greece. P. Latkoski and L. Gavrilovska are with University Ss. Cyril and Methodius, 1000 Skopje, FYR of Macedonia. O. Fratu is with Politehnica University of Bucharest, CP 060042, Romania, and R. Prasad is with Aalborg University, 9220 Aalborg, Denmark.

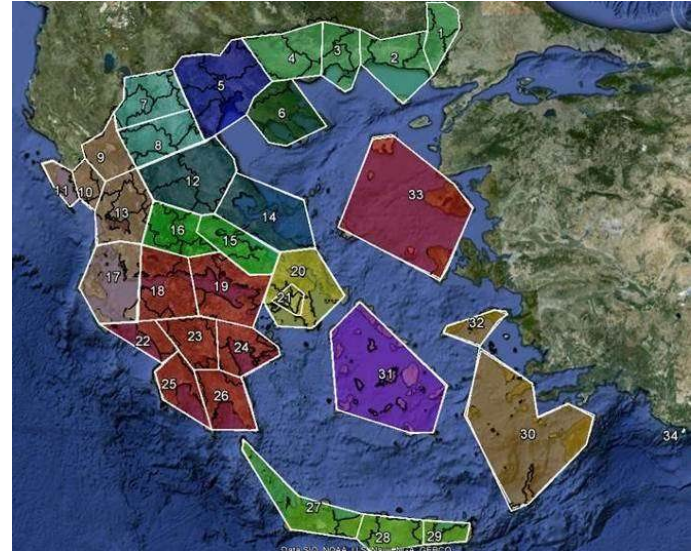


Fig. 1. Allotment zones in Greece.

Table 1. Allotment zones in Greece.

ALLOTMENT	AREA	ALLOTMENT	AREA
1	EVROS	19	KORINTHOS
2	PLAKA	20	ATTIKH(SFN-1)
3	THASSOS	21	ATHINA(SFN-2)
4	PAGGAIO	22	PYRGOS
5	THESSALONIKI	23	TRIPOLI
6	XALKIDIKI	24	NAFPLIO
7	FLORINA	25	KALAMATA
8	METAKSAS	26	SPARTI
9	IOANNINA	27	WEST CRETE
10	THESPROTIA	28	CENTRAL CRETE
11	KERKYRA	29	EAST CRETE
12	LARISSA	30	DODEKANISA
13	AKARNANIKA	31a	KYKLADES(SFN-1)
14	VOLOS	31b	KYKLADES(SFN-2)
15	LAMIA	32	SAMOS
16	KARPENISI	33	LESVOS
17	AINOS	34	KASTELLORIZO
18	PATRA		

I. FREQUENCY PLANS AND ALLOTMENTS

The Regional Radiocommunication Conference held in Geneva in 2006 (RRC 06) is considered to be the most important ITU (International Telecommunications Union)

event in the process of digital broadcasting planning, [1]. According to the ITU, the transitional period with simultaneous analogue and digital broadcasting should end on 17/05/2015 for the whole of the world. In Greece the digital transition should be completed by the end of 2014. However, in the region of Thessaloniki the ASO already took place in the end of 2012 and only DTV signals are being used since then. The allotment zones depicted in Fig. 1 are shown in Table 1, [2].

According to the ITU, allotments are geographical areas whose main purpose is less interference between them, when transmitting digital signals. In order to set an allotment, the allotment boundaries must be defined, and a maximum acceptable interference level among the allotments must be fixed. Greece is located in the Southeastern Europe and has a population of around 11 million people. The terrain morphology of Greece is extremely diverse, with mountains, covering almost 60 percent of its land, with 16.300 km coast line and 6000 islands of which only 117 are inhabited. The Greek Ministry of Transport and Communications, is the responsible authority for the country's representation in the ITU. Greece is divided in 34 allotment zones for DVB-T broadcasting purposes, in order to achieve full national coverage. Modulations of 16 QAM and 64 QAM types are used, 8K carriers, FEC 2/3 and 3/4 and guard interval (GI) that varies from 1/4 to 1/16 is used, [3]. For the video compression the standard MPEG-4 part 10-AVC (also known as ISO/IEC 14496-10 or ITU H.264) is used [4], while some local TV broadcasters still use the MPEG-2 standard for video compression. The allotment zones for Greece are shown in Fig. 1.

II. SPECTRUM MEASUREMENTS PRE- AND POST-ASO

The measurements equipment consists of a Rohde & Schwarz FSH-3 portable spectrum analyzer, factory calibrated with $\pm 0.7\text{dB}$ accuracy, two high-precision calibrated biconical antennas by Schwarzbeck, SBA 9113 (500MHz - 3GHz) and BBVU 9135 (30MHz - 1000MHz), a log-periodic precision calibrated Schwarzbeck antenna USLP 9143 (0.25 – 6 GHz), factory calibrated with $\pm 1.0\text{dB}$ accuracy, and low-loss cable Suehner GX-07272-D, 1.8 meters long with N-type connectors, [5-6]. Also, a commercial Iskra P20 log-periodic antenna is used in some measurements. This low-cost short 10 dipoles antenna has, in the UHF-TV band, similar gain as the professional USLP9143 at around 6-7 dBi, relatively flat across the whole band.

In Fig. 2 the UHF-TV band spectrum before the Analogue Switch-Off and during the simulcast period of analogue and digital TV is depicted. The spectrum occupancy is seen to be very dense with a very limited number of free TV channels (TVWS – TV White Spaces).

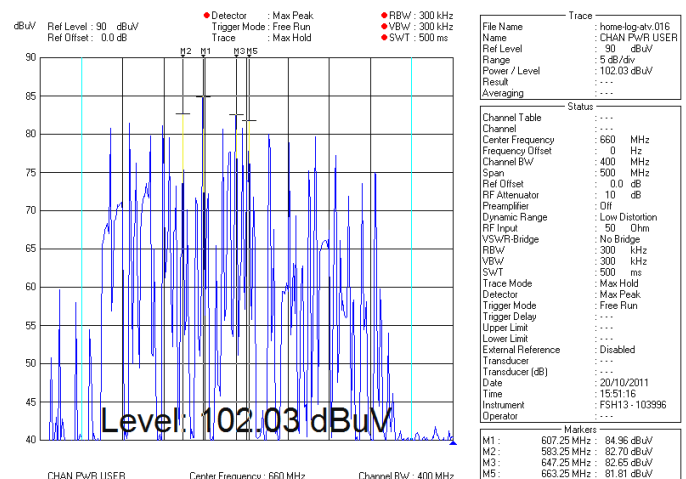


Fig. 2. UHF-TV Band spectrum during the simulcast period, Thessaloniki centre - 20/10/2011.

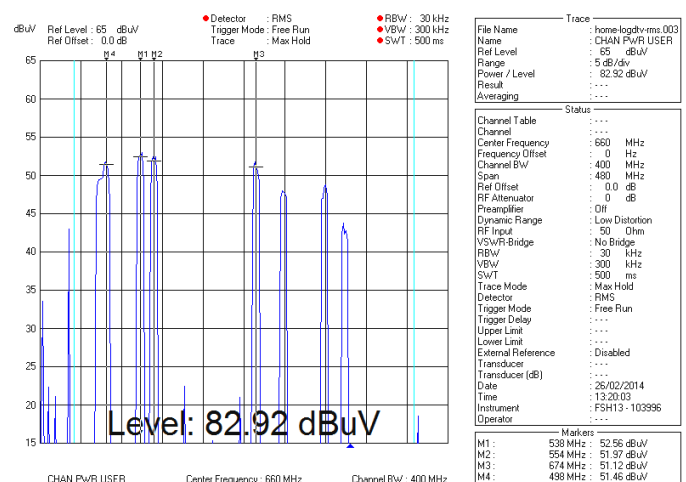


Fig. 3. UHF-TV Band spectrum after the ASO (14/12/2012), Thessaloniki centre - 26/02/2014.

However, as seen in Fig. 3, the situation post-ASO (after the 14th of December 2012) changes dramatically. Now, there are plenty of unoccupied TV channels. In fact, the only occupied channels are 8 (MUXs-Multiplexes) which carry all of previous TV Broadcasting programmes. These 8 UHF-Channels are: 23, 24, 29, 31, 46, 50, 56, 59. The digital dividend frequencies 790-862 MHz (UHF-Ch 61-69) are unoccupied, and are going to be used by LTE 4G cellular network operators. Apart from the freeing of the vast majority of TV channels, another very important characteristic of the post-ASO period is the much lower signal levels used by DTV. The 10 kW PEP (Peak Envelope Power) analogue transmitters were replaced by 1-2.5 kW RMS DVB-T transmitters, leading to 8-10 dB lower signal strengths that are sufficient for the more sensitive digital receivers, [7].

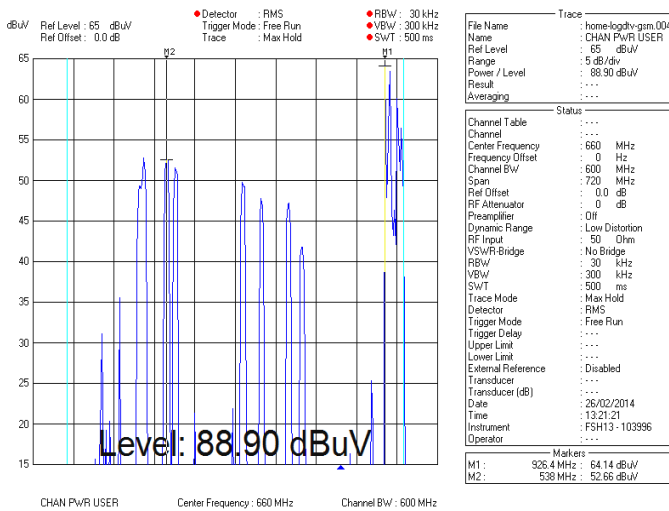


Fig. 4. UHF-TV Band plus GSM900 spectrum after the ASO (14/12/2012), Thessaloniki centre - 26/02/2014.

Another, important detail that could potentially create interference, is the vicinity of the cellular frequency bands to the top of the UHF-TV band. In Fig. 4, the spectrum of the UHF-TV band is depicted together with the GSM 900 MHz cellular frequency band. The measurement was performed with a directional log-periodic antenna pointed to the direction of the TV antenna park on Hortiat's mountain at a distance of approximately 12 km, East – Southeast of the city centre. However, in the close vicinity of the reception point at a distance of 100m and at an angle of approximately 60 degrees there is a GSM base station. Although a minimum of 16 dB signal reduction is expected at that angle, due to the directivity (and polarization) discrimination of the TV reception antenna, [8], the downlink GSM signal in the range of 920-960 MHz is very strong, at least 10 dB above the TV signals. This kind of strong signal could easily overload some reception preamplifiers, distribution amplifiers, or even TV receiver front-ends.

Table 2. Measured field-strength in Thessaloniki centre before ASO.

No	TV Station Name	UHF TV Channel	Frequency (MHz)	Field Strength Measured (dB μ V/m)
1	m.TV	38	607.25	104.8
2	SKAI	35	583.25	102.3
3	ALPHA	45	663.25	102.3
4	ALTER	41	631.25	100.7
5	ET-3	27	519.25	100.0
6	STAR	51	711.25	99.6
7	MEGA	24	495.25	99.0
8	NET	30	543.25	98.8
9	TV-100	33	567.25	98.7

Table 3. Measured field-strength in Thessaloniki centre after ASO.

No.	TV Station Name	UHF TV Channel	Frequency (MHz)	Field Strength measured (dB μ V/m)
1	DT MUX1	23	490	90.8
2	Digea MUX1	24	498	93.1
3	Digea MUX2	29	538	95.0
4	PERTHO	31	554	94.6
5	DP	46	618	94.5
6	DBS	50	706	90.6
7	DT MUX2	56	754	92.0
8	DU	59	778	86.9

The situation is expected to become even worse when LTE 4G transmissions begin in the digital dividend frequency 800 MHz band of 790-862 MHz where no filtering was foreseen in older TV reception equipment and amplifiers. In Table 2 the 9 strongest TV signals are depicted in the pre-ASO period in the centre of Thessaloniki. The reception is performed on the rooftop of a 6-floor building with clear unobstructed view to Hortiat's mountain antenna park. The field-strength values are quite high (in the range of 105 - 100 dB μ V/m) and in any case much higher than the 70 dB μ V/m value that was recommended for adequate analogue TV coverage. Almost all TV channels were used at that time, thus eliminating the notion of TV white spaces. On the contrary, in the post-ASO era, only 8 TV channels are occupied, as seen in Fig. 3, and their field-strength values are much lower (in the range of 95 - 87 dB μ V/m), *cf.* Table 3. Notably, there is a big white space of 112 MHz from 558 to 670 MHz, situated between Ch 31 and 46. Furthermore, the total received signal power in the UHF-TV band post-ASO is 19 dB lower than in the simulcast period (83 dB μ V instead of 102 dB μ V).

Similar spectrum measurements were likewise performed in the city of Skopje, FYR of Macedonia, that is of comparable size and population as Thessaloniki, [9]. The measurements were performed in the centre of the city of Skopje (Boulevard Partizanski Odredi) in clear unobstructed view of the antenna park of mount Vodno that is situated around 4 km to the South of the measurement point. The receiving antenna is placed 10 m above ground level and is a directional log-periodic antenna. Also in this case it is seen from Fig. 5 that during the simulcast period most of the TV channels were occupied and there were scarce opportunities for secondary spectrum usage. On the contrary, in the post-ASO era only 6 TV channels are occupied: Ch 23, 26, 28, 30, 33, and 52, *cf.* Fig. 6 and Table 5. Channels 23 and 52 are being used by public TV and the rest for the private and subscriber TV networks. The field-strength levels are lower in the post-ASO period for the public broadcaster, but somewhat higher for the other broadcasters, as depicted in Tables 4 and 5. In this case there is an even bigger white

space of 144 MHz between the frequencies 574 and 718 MHz, i.e. between Ch 33 and Ch 52, that could advantageously be used for secondary opportunistic transmissions. It is also clearly observed that the digital dividend 800 MHz band from 790 to 862 MHz (former TV Channels 61-69) is unoccupied and ready to be used by cellular operators.

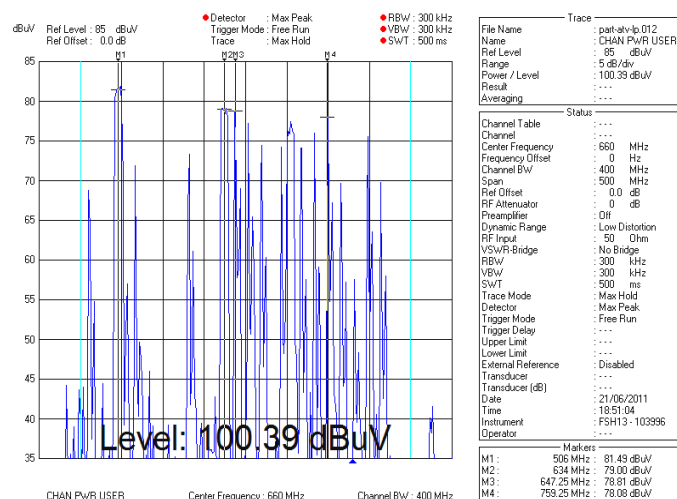


Fig. 5. UHF-TV Band spectrum during the simulcast period, Skopje centre - 21/06/2011.

Table 4. Measured field-strength in Skopje centre before ASO.

No.	TV Station Name	UHF TV Channel	Frequency (MHz)	Field Strength Measured dBuV/m
1	Sitel	57	759.25	99.7
2	Telma	43	647.25	99.1
3	TV Skopje	63	807.25	98.1
4	Mak Spot	55	743.25	97.3
5	ERA	53	727.25	95.2
6	A1	47	679.25	95.1
7	Kanal 5	50	703.25	95.0
8	MTB-3	36	591.25	92.9
9	MTM	28	527.25	90.6

A quantitative assessment of the TV White Space (TVWS) potential to support WiFi-like usage, prior and after the DSO in the city of Skopje was made. The analysis focused on one particular geographical point located within the premises of the Faculty of Electrical Engineering and Information Technologies in Skopje. The measurement setup involved an Anritsu MS2690A spectrum analyzer and a Schwarzbeck SBA9113 biconical antenna.

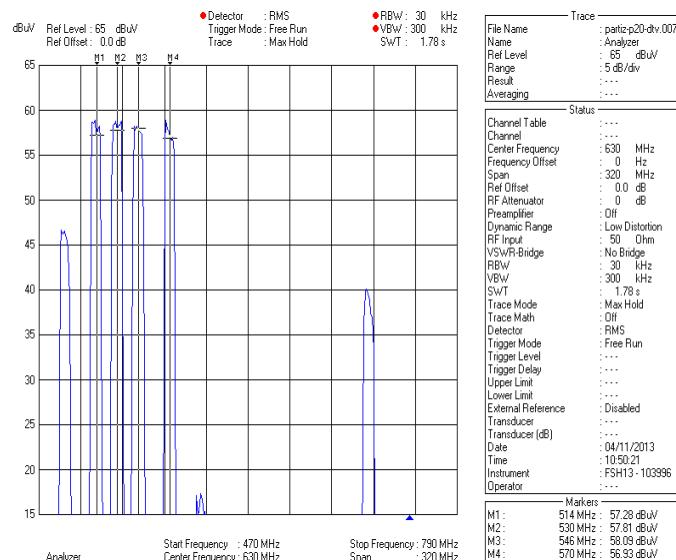


Fig. 6. UHF-TV Band spectrum after the ASO (31/05/2013), Skopje centre - 04/11/2013.

Table 5. Measured field-strength in Skopje centre after ASO.

No.	MUX	UHF TV Channel	Frequency (MHz)	Field Strength Measured dBuV/m
1	MRT	23	490	87.5
2	ONE	26	514	101.1
3	ONE	28	530	101.5
4	ONE	30	546	101.2
5	ONE	33	570	101.0
6	MRT	52	722	84.7

In order to calculate the real usable frequency chunks for secondary communication that will not degrade the operation of the primary TV reception, the analysis firstly determines the maximum received power for each TV channel. These values represent an input to the calculation process which implements the ECC rules for operation of White Space Devices (WSD) in TV band based on the SE43 Report 154 [9-10]. According to the SE43, the implementation of any WSD should not violate certain limits in degradation of the TV reception location probability. Additionally, the calculation of secondary spectrum availability needs a precise specification of the WSD regarding its transmission power and required channel bandwidth. One important input parameter in the calculation is the number of adjacent TV channels, which will be protected from the WSD transmissions. The requirement to protect a higher number of adjacent TV channels reduces the secondary spectrum availability.

The calculation of the secondary spectrum availability presented here assumes introduction of WiFi-like WSD with a transmission power of 15 dBm, located indoors where the wall penetrating loss is 5 dB. The aim is to calculate the allowable transmission power of the WSD according to the ECC rules before and after the DSO, respectively. Both cases assume protection of TV receivers operating on the same channel as the WSD, as well as ± 1 adjacent channels. Only the TV channels where the allowable transmission power is equal or higher than the assumed WSD transmission power, are eligible for operation of the secondary devices.

A quantitative study on TVWS availability prior and after DSO, would require a comparison of the secondary system performance in terms of the throughput that will be achieved by the WSDs. Figure 7 presents the achievable combined throughput of the secondary system using 8 and 16 MHz chunks prior and after the DSO and protecting ± 1 channel. This calculation assumes that the secondary system comprises of a WiFi-like access points (APs) operating on different available frequency chunks, without creating interference towards the primary receivers, nor between each other. This idealized case can be achieved if the number of secondary APs is a controllable parameter and there is also a resource manager that regulates the operational frequency of each AP. In this way, the results presented in Fig. 7 represent the upper boundary of the achievable throughput by the secondary system. Furthermore, the results give the combined MAC layer throughput from all APs, as the calculation takes into account the known performance of the Distributed Coordinating Function (DCF) for the current WiFi technology.

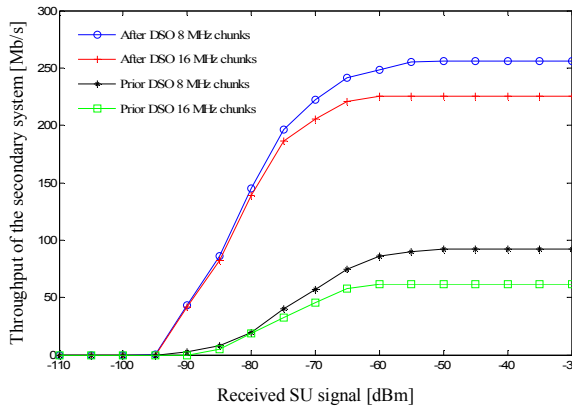


Fig. 7. Combined throughput of the secondary system using 8 and 16 MHz chunks prior and after DSO protecting ± 1 channel.

The results presented in Fig. 7 reveal that the scenario involving the TV band after the DSO, where the secondary system operates on 8 MHz frequency chunks, provides the best performance in terms of achievable throughput. The organization in 16 MHz chunks is less efficient as there are available frequency chunks with odd number of 8 MHz-channels. The achievable throughput prior to the DSO is much lower for both cases (8 MHz and 16 MHz frequency chunks operation).

IV. CONCLUSIONS

The measured UHF-TV band spectra in the cities of Thessaloniki and Skopje pre- and post-ASO clearly demonstrate the economies made on spectrum occupation by the passage to digital television. Additionally, for the same coverage area lower field-strength values are required, thus leading to lower transmitted powers. Furthermore, a study for the city of Skopje reveals that TVWS availability is much higher in the post-ASO era leading to an increased potential throughput of the secondary system in Mbits/s.

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