Journal of Electrical Engineering and Information Technologies, Vol. **8,** No. 1, pp. 19–27 (2023)
Article 204
Received: March 23, 2023
Accepted: May 5, 2023
In print: ISSN 2545–4250
On line: ISSN 2545–4269
UDC: 621.396.74.037.37
https://doi.org/10.51466/JEEIT2381204019p

Original scientific paper

DAB+ RADIO SERVICES WITH QUALITY SUPPORT IN NORTH MACEDONIA

Branko Peševski[1], Tomislav Šuminoski[2], Borislav Popovski[2]

[1]*JP Macedonian Broadcasting,*
Bulevar Goce Delčev 18, 1000 Skopje, Republic of North Macedonia
[2]*Faculty of Electrical Engineering and Information Technologies,*
"Ss. Cyril and Methodius" University in Skopje,
Rugjer Bošković bb, P.O.Box 574, 1001 Skopje, Republic of North Macedonia
tomish@feit.ukim.edu.mk

A b s t r a c t: The digitization of radio broadcasting has a long history and has been under active consideration as a project for at least 40 years. This paper will provide a brief historical development of digital radio, an overview and analysis of European and world trends today, as well as additional services offered by the DAB+ system. Furthermore, the paper includes the advantages and challenges of the DAB+ standard compared to FM analogue radio and Internet radio listening technologies, which countries have developed the standard and their planning approach. The overall development experience from the environment and the world will serve for the innovative and technological possibilities of digital radio for the future development in Macedonia. The main focus of the paper is the preparation of: DAB+ frequency planning in Macedonia, other planning and use cases, as well as a pilot project for the implementation of DAB+ in Macedonia. Our country is in the experimental phase and preparation for the regulation and introduction of DAB+ digital radio. It is necessary to form an interdepartmental working group (JP Macedonian Broadcasting, Agency for Electronic Communications (AEC), Ministry of Information Society and Administration (MISA), Agency for Audio and Audio-Visual Media Services of the Republic of Macedonia (AAAMS), Macedonian Radio Television (MRTV), private broadcasters, etc.) that will prepare a Strategy for the Introduction of DAB+ digital radio – each in its own part, and thus a change in the Law on electronic communications.

Key words;; DAB; DAB+; FM; IP; HE-AAC v2; SFN; OFDM

УСЛУГИ НА РАДИО DAB+ СО ПОДДРШКА ЗА КВАЛИТЕТ ВО СЕВЕРНА МАКЕДОНИЈА

А п с т р а к т: Дигитализацијата на радиоемитувањето има долга историја и како проект е под активно разгледување најмалку 40 години. Овој труд дава краток историски преглед на развојот на дигиталното радио, преглед и анализа на европските и светските трендови денес, како и дополнителните услуги кои ги нуди системот DAB+. Во трудот исто така се разгледуваат предностите и предизвиците на стандардот DAB+ во споредба со аналогното FM-радио и Интернет-технологиите за слушање радио, како и кои земји го развиле стандардот и нивниот начин на пристап кон планирањата. Целокупното развојно искуство од околината и светот ќе послужи за идниот развој на иновативните и технолошки можности на дигиталното радио во С. Македонија. Главен фокус на трудот е претставување на планирање на DAB+ фрекфентнции во С. Македонија, други планирања и случаи на користење, како и пилот-проект за имплементација на DAB+ во С. Македонија. Нашата држава се наоѓа во експериментална фаза и подготовка на регулација и воведување на дигиталното радио DAB+. Потребно е формирање меѓуресорска работна група (ЈП Македонска радиодифузија, АЕК, МИОА, АВМУ, МРТВ, приватни радиодифузери и др.) која ќе подготви стратегија за воведување дигитално радио DAB+ – секој во својот дел, а со тоа и промена на Законот за електронски комуникации.

Клучни зборови: DAB; DAB+; FM; IP; HE-AAC v2; SFN; OFDM

1. INTRODUCTION

Digital technology for the development of radio transmission begins with the DAB system which was developed in 1981 by the Institut für Rundfunk Technik (IRT). Project Eureka 147 was established in 1985 by the European Union to encourage a bottom-up approach to technological development and to strengthen the competitive position of European

companies on the world market. The Eureka 147 consortium was founded in 1987 with 16 partners from the EU, and Germany, France, the Netherlands and the UK are the holders. The Eureka 147 standard was defined in 1993 with International Telecommunication Union (ITU) recommendations published in 1994 and an initial ETSI standard published in 1995. Eureka shut down the Eureka 147 project on January 1, 2000. WorldDAB was established in 1995 to encourage international cooperation and coordination to introduce DAB to the consumer market. Technical work previously carried out by Eureka 147 is now carried out within the Technical and Commercial Committees of WorldDAB. The DAB/DAB+ is defined by international ITU recommendations, European Telecommunications Standards Institute (ETSI), European Committee for Electrotechnical Standardization (CENELEC), International Electrotechnical Commission (IEC) standards and national standards (e.g. Australian, British standards for receivers) [1–4].

WorldDAB, the organization responsible for DAB standards, released DAB+ the major upgrade to the DAB standard in 2006, when the HE-AAC v2 audio coded (also known as AAC+). The AAC+ uses a modified discrete cosine transform (MDCT) algorithm. The new standard, called DAB+, adopted both the MPEG Surround audio format and stronger error correction coding in the form of Reed-Solomon coding.

DAB+ is standardized by the European Telecommunications Standards Institute (ETSI) [4]. As DAB is not backwards compatible with DAB+, older DAB receivers cannot receive DAB+ broadcasts. However, DAB receivers that will be able to receive the new DAB+ standard via an upgrade went live and on sale in July 2007 [5–10].

Existing analog AM and FM systems suffer from inherent shortcomings and neither can offer uniform reception quality across the entire coverage area. AM radio reception is limited by bandwidth limitations that limit sound quality and by interference from other co-channel and adjacent broadcast channels, and this is particularly problematic during night-time hours. Analogue FM terrestrial broadcasting has been pushed to its limits in terms of technology and programming, and the available frequencies have already been allocated. There is almost no room for new channels, services and technical innovations. The FM radio market has become a limiting field, thus limited to current broadcasters. This imbalance at the expense of commercial providers is under criticism because historically based, public broadcasters have more FM frequencies available to them. The DAB+ puts an end to this and revives competition for the benefit of the listening public. The DAB+ is the perfect complement to the Internet and vice versa, but the Internet streaming platform is not a substitute for DAB+. Despite the Internet, terrestrial transmission of radio programs allows their anonymous and free use without audio restrictions.

DAB+ is a synonym for diversity, quality and innovation of the programs, and at the same time it provides innovative radio stations with practically unlimited opportunities for their program development and for new programs of special interest. Another aspect of AM and FM analog transmissions is the inefficient use of spectrum (relative to what is possible using digital technology). There are many ways in which digital radio systems can improve upon analog systems such as [3, 5]:

• Digital signals are more robust than analogue and can be transmitted successfully at lower transmitter powers.

• Digital systems using coded multicarrier modulation offer much improved reception on mobile car radios and portables.

• Advanced digital compression techniques enable low bit rates to be used successfully, whilst still producing sound of near CD quality. This makes digital systems more spectrum efficient.

• The digital bit-stream can be used for transmitting both audio and data.

• A digital radio is much easier to use/tune than an AM/FM radio.

• The data capability of digital radio can be used directly or combined with activities such as Internet radio.

According to the latest research and studies with different scenarios in Europe and the wider world, using three different transmission platforms: FM, DAB+ and IP-DAB+ digital radio is the most affordable way to broadcast radio [7–5].

While traditional receivers are still the dominant device for listening to radio, using a smart radio as a receiver – Hybrid Radio is the Future. Hybrid radio seamlessly combines radio broadcasting and the Internet. A broadcast signal (FM, HD, DAB, DAB+) continues to transmit audio (and some data), but a radio with an Internet connection (WiFi, 3G, 4G, LTE, 5G) can seamlessly connect to the station

for multimedia and interactivity. Hybrid radio is evolving with standards and better combines broadcast with the radio that the Internet is creating. At the same time, the range of listening options, whether involving mobile, fixed or portable devices, smart Hybrid radios has expanded significantly, especially in cars. Music, streaming platforms, podcasts and other formats that aren't radio in the traditional sense are all competing for listeners [7, 12, 13].

Today, DAB+ has established itself as a new standard for radio transmission throughout Europe, and even more widely around the world – also called green radio. In terms of radio broadcasting, studies have shown that DAB+ has the lowest energy consumption, and a hybrid approach of DAB+ and IP will achieve the greatest energy savings [14, 15].

2. DAB+ IN EUROPE AND THE WORLD TODAY

The DAB+ system is a sound, video and data broadcasting system with high efficiency and power. It uses industry standard audio and video encoding techniques to remove redundancy from the source signals, it then applies closely controlled redundancy to the signal to be transmitted to provide strong error protection. The transmitted information is spread in both the frequency and time domains so that the defects of channel distortions and fades can be eliminated from the recovered signal in the receiver, even when working in conditions of severe multi-path propagation, whether stationary or mobile. Efficient spectrum utilization is achieved by interleaving multiple programmed signals and, additionally, by a special feature of frequency re-use, which permits broadcasting networks to be extended, virtually without limit, by operating additional transmitters carrying the same multiplexes on the same radiated frequency. The latter feature is known as the Single Frequency Network (SFN) [4].

The DAB+ standard is characterized by the following advantages and challenges [3, 7]:

Advantages:

- It is an open standard with no annual license fees to be paid by broadcasters.
- It can be implemented for a range of applications such as wide area or local delivery of audio and data services for mobile, portable and fixed reception.
- It can be delivered terrestrially.
- It is designed to be used across a wide spectrum range, from 30 to 300 MHz.
- It uses a wideband COFDM modulation system which provides a robust transmission which is multipath resilient and can provide high availability coverage.
- It can be implemented using on-channel repeaters in Single Frequency Networks (SFNs) or low power gap fillers and extenders. SFNs may also provide “network gain” giving improved service availability over single channel services.
- It can accommodate a varying number of audio services of differing quality with associated data. The audio quality can range from simple monospeech to high quality stereo.
- Data can also be delivered independently of the audio services, and standardized applications exist to enhance the audio service with visuals, program guides, and others.
- It uses mature technologies such as MPEG 1 Layer II (DAB) and HE AAC v2 (DAB+) audio coding systems and COFDM modulation, which are also used in the DVB-T video broadcasting standard. This has led to low cost single chip solutions for receivers.
- It has been standardized by international ITU recommendations, ETSI, CENELEC, IEC standards and national standards (e.g., Australian, British receiver standards).
- A large number of receivers are available for portable, PCs, mobile, in-car and in-house reception. Receiver prices continue to fall and hit rock bottom. DAB+ transmission has been shown to be an environmentally friendly technology when compared to FM.
- The standards include a number of features which can be used to implement Emergency Warning Systems and functionality including: automatic power on from standby through Emergency Warning signaling (Automatic switching of services to a specific Emergency Broadcast both within an ensemble or on a different ensemble, plus various multimedia support including text, images and applications).
- Well placed to be part of a Hybrid radio future, with terrestrial broadcast carrying audio and small data services alongside IP connectivity offering additional higher bandwidth services, personalization and backchannel interactivity.

Challenges:

- The MPEG 1 Layer II audio coding systems are now dated (compared with new systems) but they offer excellent robustness against channel errors due to unequal error protection (UEP). Most countries which adopted DAB are now converting to DAB+ to take advantage of the higher efficiency delivery – up to 2.5 times as many services can be delivered using DAB+ compared to DAB.
- While a wide range of low cost DAB receivers are already available, they are still generally seen as being too costly for general public acceptance in developing countries, particularly when compared to the very low cost AM and FM radios that many listeners currently use. As integration increases and single (RF + Baseband) chips become the norm, prices continue to fall and are expected to reach acceptable prices in those countries in the near future.
- The standard capacity of DAB+ using rate ½ FEC is 1.152 Mbps. Given a bit rate per service of 64 kbps, a single DAB+ ensemble can carry 18 services. In a conversion model, this may sometimes pose challenges for some radio broadcast markets, which are typically served by a mixture of narrowcasting, community, commercial and national services using AM and FM frequencies.
- The requirement for multiplexing will over time reduce the number of transmission sites and result in more consistent and cost effective coverage of digital radio services.

Although FM coverage still exceeds DAB/DAB+ coverage in most countries implementing any type of DAB+ service, a number of countries undergoing digital radio switchover are undergoing significant DAB+ network expansions, as of December 2019, WorldDAB provided the following worldwide population coverages (expressed in %):

Kuwait 100; Malta 100; Monaco 100; Vatican 100; Norway 99.7; Switzerland 99.5; Denmark 98; Germany 98; UK 97.3; Belgium 97; Netherlands 95; Gibraltar 90; South Korea 90; Czech Republic 85; Slovenia 85; Italy 84; Austria 77; Australia 65; Poland 56; Ireland 52; Tunisia 51; Sweden 41.8; Azerbaijan 30; France 25; Spain 20; Ukraine 7.07 [8, 10].

The digital world map of DAB/DAB+ network coverage provided by WorldDAB is presented in Figure 1 and that of three types of countries according to their development and implementtation: countries with regular services, countries with tests and/or regulations, and countries with interest.

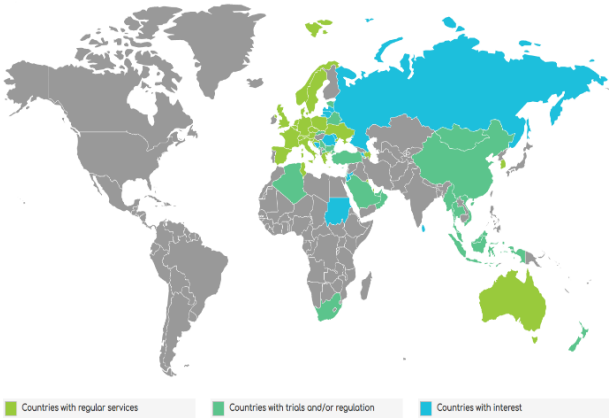


Fig. 1. Coverage of DAB/DAB+ network countries around the world [8]

There are also digital leaders, which are the countries at the forefront of digital radio according to most indicators, including wide coverage, expanded offering of new services, advanced legislation and regulation, including criteria and sometimes even switchover dates.

Countries with incomplete radio coverage are those where DAB+ has been launched nationally, with exclusive services (different from analogue broadcasting), receivers are on the market, promotional campaigns are underway and penetration is growing (at different rates). Digital Novices are those countries that have recently launched DAB+ services, with exclusive stations but limited coverage (specific cities or regions) and limited or lack of commitment from some key stakeholders. Let's see and wait for those countries, where regular digital radio services or trials are available, but there is almost no market due to lack of receivers but also in general, lack of commitment from the various stakeholders. Often this is also related to non-permanent launch of services.

The data included in the infographic shown in Table 1 for DAB/DAB+ is provided by WorldDAB members and partners including market research agencies, broadcasters, national digital radio bodies, national ministries, government bodies. WorldDAB collects the latest available DAB+ data on receiver sales, new car sales, population coverage, household penetration, road coverage, national DAB+ stations, digital radio reach, listening numbers, emerging markets. Updated and published twice a

year, the WorldDAB infographic includes important DAB+ data and figures for broadcasters, receivers and car manufacturers as well as listeners [6 – 9].

Digital Radio Standards more than 80% of digital stations use DAB+, while the DAB standard continues to phase out.

3. DAB+ PLANNING IN MACEDONIA (USE CASES)

For the commissioning of DAB+ equipment with a power of 500 W at JP Macedonian Broadcasting (JP MB) for the use of radio frequencies in the broadcasting service of digital radio (T-DAB), a temporary approval valid from 10.07.2019 to 09.07.2020 was received from AEC at the point Vodno - Skopje. The approval was issued for the use of radio frequencies for experimental purposes, for a limited area of coverage, for the purpose of introducing new technologies for a period not exceeding one year. During this period the DAB+ signal was broadcast without any problems.

T a b l e 1

DAB/DAB+ infographic data [6, 8]

Countries	Sales of cumulative DAB/DAB+ receiver 2008 - 2021	New cars with DAB/DAB+ %	DAB/DAB+ network coverage 2013 % 2021%	Road coverage DAB/DAB+ Km %	DAB/DAB+ household receiver penetration	Number of national FM DAB/DAB+ stations
United Kingdom	48.198 000	98%	94% 97.3%	46.000 km 87%	67%	8 56
Germany	21.600 000	94%	91% 98%	12.700 km 98%	27%	2 29
Italy	8.095 000	100%	65% 84%	6.500 km 95%	13%	21 50
Norway	7.000 000	100%	89% 99.7%	7.500 km 97%	73%	0 32
Australia	6.941 000	82%	63% 64%	/ 94%	51%	/ /
Switzerland	5.694 000	100%	99.5% 99,5%	1.450 km 99%	/	54 70
France	5.428 000	90%	8% 39%	/ /	13%	/ /
Netherlands	2.827 000	95%	/ >95%	4.800 km 95%	/	13 29
Belgium	1.887 000	98%	95% 97%	1.675 km 95%	21%	29 55
Denmark	1.547 000	94%	98% 99.9%	1.300 km 99%	36%	6 21

The 8 radio programs were broadcast on MRTV (4 program services used analog input (left and right audio channel), and 4 program services used digital AES/EBU input). The propagation was excellent because the DAB+ signal was heard without problems within a radius of about 50 km from the transmission point of RDO Vodno. In this way, it was possible for citizens who have appropriate receivers to familiarize themselves with the advantages of this technology. Then JP MB stopped broadcasting the DAB+ signal, because it did not receive a permission from AEC to continue broadcasting [6].

The JP MB launched an initiative to the Ministry of Information Society and Administration, for necessary legal changes (additions, adjustments and inclusion) of all stakeholders in the process for the introduction of DAB+ digital radio in the Republic of North Macedonia. Currently, there are 66 private FM radios and 4 radios from the national service (3 FM + 1 AM), of which 4 private and 4 from the national service cover the entire territory of the State, and the others are regional and local [6].

The DAB or DAB+, uses the VHF III frequency range of 174 to 240 MHz for transmission. The channel width is 7 MHz, which is divided into 4 DAB blocks, resulting in 4 DAB channels in one VHF channel (i.e. 12A, 12B, 12C and 12D). Each block is 7/4 MHz wide, i.e. 1.75 MHz, of which 1.536 MHz is used, and the rest is protection from adjacent channels. At the RRC-06 conference of North Macedonia has been assigned two allotment zones (Macedonia northeast and Macedonia southwest), shown on the division map of North Macedonia – Figure 2. At the same time, two multiplexes have been agreed for each allotment zone in the VHF area (174 – 240 MHz), presented in Figure 2. Channels 11 and 12 are intended for terrestrial sound broadcasting (T-DAB). Channels 11 and 12 intended for T-DAB are divided into blocks, where each channel contains 4 frequency blocks with a width of 1.75 MHz [6, 11].

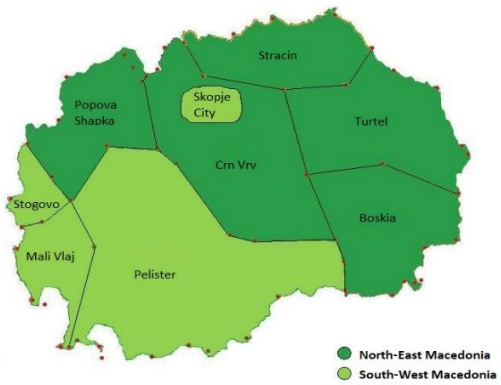
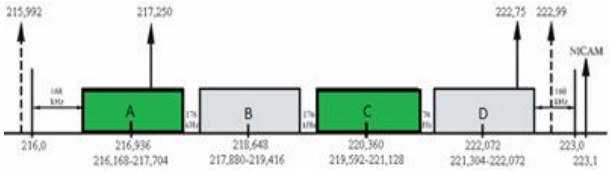
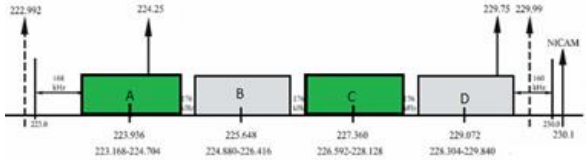


Fig. 2. SFN allotment zones in North Macedonia

Figure 3 shows the layout of DAB+ blocks for VHF channels 11 and 12 – on N. Macedonia. According to the frequency planning of the RRC-6 conference, i.e. AEC, Macedonia has been assigned – 11A and 12A (southwest and Skopje city), 11C and 12C (northeast) shown in Table 2 by blocks and frequencies [6, 11].



a) Schedule of DAB+ blocks in the 11th VHF channel



b) Schedule of DAB+ blocks in the 12th VHF channel

Fig. 3. Layout of DAB+ blocks in VHF channels 11 and 12

T a b l e 2

Frequency blocks for North Macedonia

Blocks	Range of blocks	Carrier	Allotment zones
11A	216.160 MHz – 217.696 MHz	216.936 MHz	south-west (SW) Skopje city
11C	219.584 MHz – 221.120 MHz	220.360 MHz	north-east (NE)
12A	223.168 MHz – 224.704 MHz	223.936 MHz	south-west (SW) Skopje city
12C	226.592 MHz – 228.128 MHz	227.360 MHz	north-east (NE)

The JP MB, taking into account the topology and population of the country – according to the analyses and propagation planning, to implement the DAB+ system by upgrading the infrastructure, mounting antenna systems and putting digital radio transmitters into operation at more than 30 broadcasting facilities throughout the territory of North Macedonia. With the planned antenna systems and powers of the DAB+ transmitting devices with which the DAB+ program will be broadcast on more than 30 broadcasting facilities in the network of JP MB in an 1+1 system, about 90% of the territory and roads of the Republic of North Macedonia will be covered at this stage. Further, with measurements and planning, it will be determined with how many transmitters (with which powers) to cover the rest of the territory of North Macedonia (from about 10%).

For the transmission of the DAB+ signal to all broadcasting facilities that are planned to broadcast it, the existing digital IP microwave link network would be used, which is currently available at around 85 locations of JP MB and which operates in a 2+0 system (2×155 Mbit/s). DVB-T multiplexes are currently being transmitted and broadcast through a digital IP microwave network to all those 85 locations of JP MB as well as the FM MPX signal using MPX/IP and IP/MPX converters.

However, for successful implementation of DAB+, it is necessary to design and perform new DAB+ antenna systems, but also larger infrastructure projects – in the construction part, steel structures and in the energy segment [6].

4. PILOT PROJECT FOR IMPLEMENTATION OF DAB+ IN NORTH MACEDONIA

The conceptual solution and conceptual project of the Antenna System for DAB+ (Kula Vodno), with general data given in Table 3, was jointly developed by the Submitters of the prepared paper and the companies Jampro Antennas from Sacramento (USA) and AlanDick Broadcast (Great Britain) with their specialized programs for that purpose. The proposed system is a vertically polarized DAB+ antenna system with 6 floors per vertical. Each element is arranged around the FM element with 2 DAB+ levels for one FM level. The DAB+ Dual Dipole is designed to give omni-directional with, a 4-way all-around configuration [6].

T a b l e 3

General data for the DAB+ antenna system

General Data	
Operating Frequencies	216 – 230MHz
Polarisation	Vertical
Horizontal Pattern	Omni-directional
Nominal Beam Tilt	5°
Null Fill	>12%
Antenna Aperture	8m
Number of Main Feeders	2
Antenna Input	1 5/8" EIA
Antenna Input Impedance	50 ohm
Maximum IP Power	3 x 2kW

Figure 4 shows the horizontal radiation characteristic, and Figure 5 shows the Block diagram of the DAB+ Antenna System with the arrangement of antennas, dividers, connecting cables and other elements.

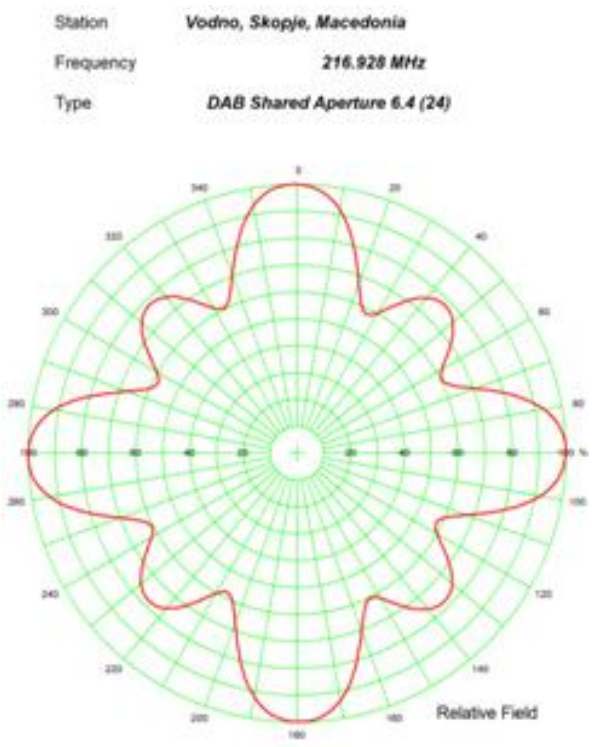


Fig. 4. Horizontal characteristic of radiation

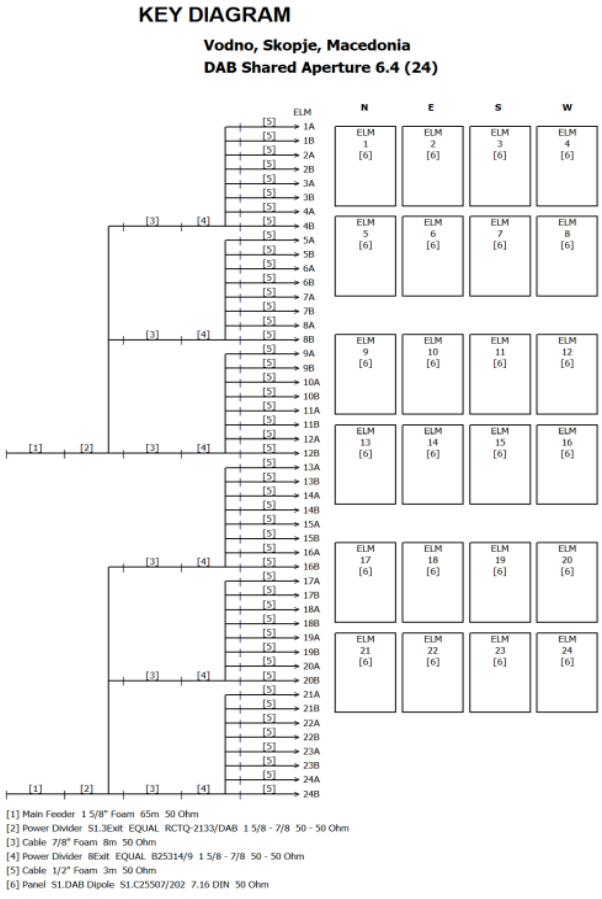


Fig. 5. Block diagram of the DAB+ Antenna System, Kula Vodno

Coverage predictions are made by software, taking into account the coverage parameters – shown in Table 4. Among other things, they take into account the use of land and buildings in the intended coverage areas and will be subject to some degree of variation depending on local conditions. The clutter databases used are Corine and Globcover. The database may not represent the exact land use at the time of the simulation.

T a b l e 4

DAB+ coverage parameters

Coverage Parameters	
Terrain Data:	SRTM 1 arcsecond 30m Resolution
Land Cover:	Corine and Globcover Clutter Databases
Model parameters:	
Surface refractivity (N-Units):	301
Ground Conductivity (S/m):	0.005
Ground Permittivity (Farads/m)	15
Climate:	Continental Temperate
Propagation Model	ITM (Irregular Terrain Model)
Probability	70% of situations 50% of time 50% of locations
Transmitting Site:	
Type:	Vertical Dipole
Mean Height	133.5m Shared FM Aperture
Transmitter Power	1kW
System Gain	9.3dB
Outdoor Receiver Parameters:	
Height:	10m / 1.5m
Gain	0dB
Recommended Minimum field strengths	54dBuV/m better than 95% 47dBuV/m better than 70%

SRTM1 30 m, resolution terrain data were used for this coverage prediction for 1 kW transmitter (Tx) power and the shown antenna system, for 1.5 m receiver height – Figure 6 [6]. The Figure 6 shows a coverage map in the region with a DAB+ signal field strength of 47 – 100 dBμV/m, shown in various colors. The coverage results were obtained with software solutions made by the mentioned companies, for the given parameters and antenna system for DAB+.

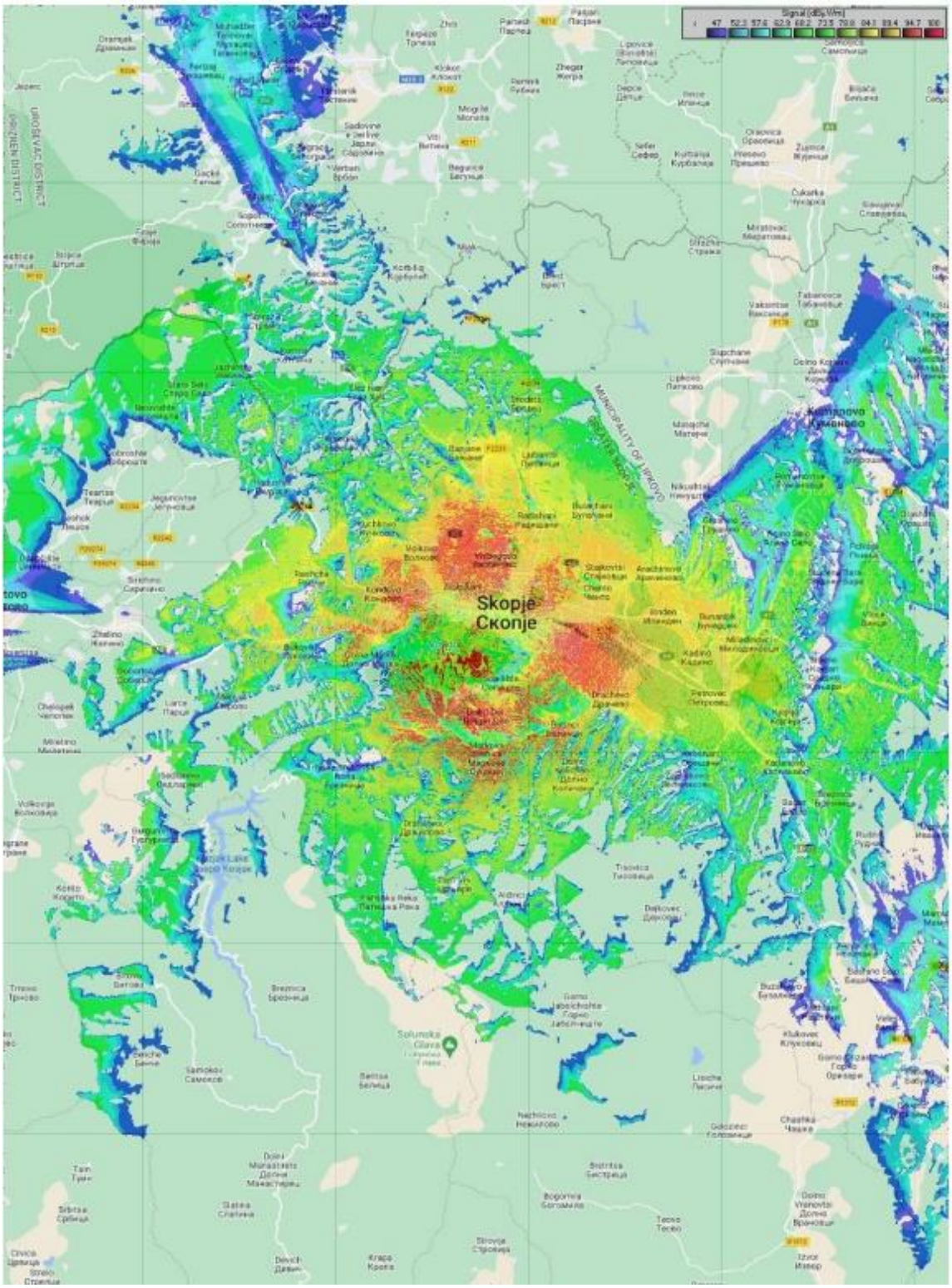


Fig. 6. 1kW TX coverage prediction (1.5 m receiver height)

5. CONCLUSION

This paper presents a platform or standard for broadcasting a system designed for digital audio broadcasting DAB+ radio services, with the delivery of high quality support of digital audio, video programs and data services for mobile, portable and fixed reception from terrestrial transmitters in the frequency bands (VHF III) in the Republic of North Macedonia. The DAB+ system is designed to provide spectrum techniques that are energy efficient in terrestrial transmission network planning, known as Single Frequency Network (SFN) and gap filling techniques. The DAB+ system meets the required criteria for sharing with other radio communication services.

We can conclude why Introduction of DAB+ digital radio in Macedonia:

• DAB+ is the best digital radio delivery system available.

• Proven technology.

• Efficient infrastructure.

• Deployed worldwide and expanding rapidly.

• Very flexible operation for broadcasters.

• Huge range of products for receivers.

• Great features including scrolling text, images, EPG and data services.

• Many new developments including interactivity.

The fact is that there are several technological, economic and environmental aspects that make DAB+ terrestrial digital radio advantageous to use. Many, including relevant research centers and experts, have analyzed the DAB+ and FM broadcasting systems. Starting with the consumption of electricity, how the supply of electricity and its consumption will be – become crucial questions in the years and decades ahead, as well as the increasing services offered by DAB+.

Concrete planning would be crucial for the future of broadcasting. In the countries of Western Europe, both FM analog radio and DAB+ digital radio with a network of transmitters work. This is supported by practical implementations that show that DAB+ is economically and environmentally cheaper and more positive than the existing FM system. Finally, the introduction of the digital broadcasting of audio signals through the DAB+ technology, which from the european studies and researches, was recommended as the most optimal solution for the transmission of audio signals in the countries that plan to start digitalization in this area, and thus for the Republic of North Macedonia.

REFERENCES

[1] ITU-R BS.2214-5 Planning parameters for terrestrial digital sound broadcasting systems in VHF bands (10/2020) .

[2] EBU Tech 3391 – Guidelines for DAB network planning (May 2018).

[3] Digital Radio Guide – World Broadcasting Unions – Technical Committee (June 2017).

[4] ETSI EN 300 401 V2.1.1 (2017-01) – Radio Broadcasting Systems; Digital Audio Broadcasting (DAB) to mobile, portable and fixed receivers.

[5] DAB Eureka-147: The European Vision for Digital Radio (May 2008).

[6] Peševski, B. (2022): *Voveduvanje na digitalno radio DAB+*, Magistarski trud, mentor: Prof. d-r Borislav Popovski, Fakultet za elektrotehnika i informaciski tehnologii (FEIT), Univerzitet “Sv. Kiril i Metodij” vo Skopje, December 2022.

[7] Les Sabel (May 2019), *Overview of the DAB+ System,* WorldDAB Technical Committee.

[8] Internet sources on the subject https://www.worlddab.org/ (WorldDAB).

[9] WorldDAB Automotive DAB Digital Radio In-car User Experience Guidelines (January 2022 – v.37).

[10] *Digitalni radio standard* – WorldDAB, Globalni industrijski forum za digitalni radio.

[11] DAB+ Budućnost digitalnog radija u Srbiji (2018).

[12] *DAB+ or Mobile* – WorldDAB (2020).

[13] *Is 5G a viable solution for radio* – WorldDAB – Factsheet (2020).

[14] Green radio – Making Radio More – Sustainable with DAB+ (September 2021).

[15] EBU Technical Review (July 2017): Cost-Benifit Analysis of FM, DAB, DAB+, and broadband for radio broadcasters and listernes