Article

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Abstract

This paper presents the design and experimental evaluation of a microstrip antenna intended for operation in the DVB-T2 digital terrestrial television system within the UHF band. The antenna was fabricated on an FR4 dielectric substrate with a relative permittivity of and a thickness of mm. The developed structure is characterized by compact dimensions (mm), which facilitates integration with receiving devices. This paper presents the results of numerical simulations and laboratory measurements concerning the electrical performance and radiation characteristics of the proposed antenna. The analysis encompasses the reflection coefficient (), voltage standing wave ratio (VSWR), input impedance, and antenna gain. The proposed microstrip antenna is characterized by a minimum reflection coefficient (S_{11}) of –27.19 dB, a peak gain of 3.22 dBi, and a wide operating bandwidth of 640 MHz, which corresponds to a relative bandwidth of 103.22%. The experimental section of this study also includes a comparative analysis of the RF and signal quality parameters of the DVB-T2 signal. The performance of the proposed antenna was evaluated against four other receiving antennas of different configurations, specifically log-periodic and dipole designs. The analysis of the experimental data, including received signal levels and multiplex reception stability, enabled the evaluation of the developed antenna under real-world operating conditions in comparison with commercially available benchmarks. The results demonstrate that the proposed microstrip antenna provides an effective and compact alternative for DVB-T2 digital terrestrial television reception systems.

Keywords: antenna; microstrip antenna; DVB-T2; UHF

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1. Introduction

The DVB-T2 system represents the second generation of digital terrestrial television (DTT). This standard was designed to provide enhanced broadcast quality and improved spectral efficiency, allowing for a higher data throughput and the transmission of a greater number of services within the same frequency resources. Notably, the transition from DVB-T to DVB-T2 did not necessitate the replacement of existing receiving antennas [1,2].

If reception issues persist, it may be necessary to replace the antenna with a model featuring different radiation patterns or higher gain. Optimal antenna selection depends on several factors, including: the distance from the transmitter, transmitter emission power, the height of the transmitting antennas, and their directivity. Furthermore, the propagation environment—including topography, urban density, and the network configuration (MFN or SFN)—plays a critical role. Ultimately, the choice of antenna must guarantee adequate radio signal reception [3].

When choosing an antenna, you need to know the distance to the best transmitter (MFN)/sFN for the channel you want to receive, according to data downloaded from websites. Table 1 shows a sample range of antennas depending on the distance from the transmitter. This also allows you to know from what direction (azimuth) you should aim to receive the TV signal. In cases where direct reception from the transmitter's primary direction is unsuccessful, adjusting the antenna's azimuthal orientation may be necessary. This is particularly critical in Non-Line-of-Sight (NLOS) scenarios, where the signal is subject to multipath reflections, or in environments where the same program is broadcast by multiple synchronized transmitters. By tilting the antenna in different directions, you can receive signals reflected from surrounding infrastructure or another broadcasting station. Additionally, you need to consider where the antenna will be mounted and which multiplexes will be received. If the distance to the DVB-T2 transmitter is greater than 50%, i.e., more than half the broadcast range, an active antenna with an amplifier should be used. To maximize reception quality, outdoor antennas should be installed at the highest possible elevation, typically on rooftop masts to ensure a clear Fresnel zone. However, in dense urban environments characterized by high-rise structures, an omnidirectional antenna often proves to be a superior solution. This is because the DVB-T2 signal in such areas is frequently composed of multiple multipath reflections arriving from various directions. Compared to a directional antenna, omnidirectional antennas are capable of receiving multiple versions of the same signal reflected from obstacles. The OFDM technology used in DVB-T2 improves the quality of the received signal. The purpose of a directional antenna is to receive a television signal from one direction, usually from a transmitter located far away. This increases range and reduces the risk of interference from other emission sources. The use of internal antennas is limited to locations with strong signal strength near the transmitter. These antennas are characterized by low gain and are often paired with high-gain broadband antenna amplifiers. Even when we receive the desired signal, interfering signals will also be amplified, causing problems with unsatisfactory quality [4–7].

Table 1. Requirements for the type of receiving antenna used for the DVB-T2 signal [https://lemor.pl/jaka-antena-dvb-t-wybierz-najlepsza-antene-dla-swojego-sygnalu] [https://telewizja-cyfrowa.com/anteny-dvb-t/].

Distance from the transmitter	Recommended antenna type	Antenna amplifier	Practical notes
0-10 km	Room or simple exterior	No	Overdrive capability
10-30 km	External Directional	Optional	No additional requirements
30-50 km	High Gain Directional	Yes	Recommended LTE filter
Over 50 km	Professional Direction	Yes	High requirements for the installation location

Advancements in digital broadcasting, particularly the transition to the DVB-T2 standard, have significantly expanded the variety of available programming. This standard enables multiple digital services to be broadcast within the same frequency bandwidth previously occupied by a single analog channel. This is achieved through the transmission of a consolidated data stream known as a multiplex (MUX). A multiplex (MUX) is a digital stream comprising multiple television programs and auxiliary services transmitted over a single frequency channel. In Poland, multiplexes MUX 1 (Ch. 43, 650 MHz), MUX 2 (Ch. 29, 538 MHz), MUX 3 (Ch. 27, 522 MHz), and MUX 6 (Ch. 48, 690 MHz) provide content in HD or Full HD resolution. These services are broadcast within the UHF bands (IV and V) using horizontal polarization nationwide. Additionally, MUX 8 (Ch. 7, 191.5 MHz) operates in VHF band III, utilizing either vertical or horizontal polarization depending on the region. The domestic frequency allocation for bands IV and V spans from 470 MHz to 694 MHz, while band III covers 180 MHz to 300 MHz.

Each antenna architecture possesses distinct advantages and limitations tailored to specific deployment scenarios. The selection process must account for local propagation conditions, the receiver's geographic location, and the radiation characteristics of the targeted transmitter. For optimal DVB-T2 reception, it is recommended to utilize broadband antennas covering the UHF (channels 21–48) and VHF (channels 5–12) bands, or a combination of band-specific antennas integrated via a diplexer [1–3]. The article presents comparative measurements of radio and quality parameters used to describe the DVB-T2 signal using the designed and discussed microstrip antenna and four other receiving antennas available on the market with different designs, logoperiodic and dipole, suitable for television bands IV and V (UHF)[8,9].

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2. DVB-T2 Microstrip Antenna Model

Due to the frequency ranges used by the DVB-T2 system in Poland, the main assumption for the designed microstrip antenna is to operate in one of these frequency bands. Since four of the five multiplexes are broadcast in the UHF band, this band was chosen. Besides the frequency band, other important requirements for the designed antenna include the antenna dimensions, which should not exceed 200 x 200 mm, and the type of material from which the antenna is to be made. The commonly used FR4 laminate was selected for the antenna design. The FR-4 laminate is a glass-epoxy material covered with a copper layer. The selected material has a thickness of h = 1.6 mm, an electrical permittivity of $\varepsilon r = 4.4$, and low loss $\tan(\delta) = 0.03$.

For the assumed antenna parameters, a model was developed in CST Microwave Studio microstrip antenna design software. This software allows for determining the electrical parameters and radiation characteristics of the antenna [10,11]. Initially, the antenna design primarily considered the S_{11} coefficient and the antenna gain G. Utilizing CST Microwave Studio, a final optimization process was conducted to ensure the model met all design requirements. This involved iteratively adjusting the antenna's geometry and feed configuration. Specifically, the lengths and widths of the dielectric substrate, the ground plane, the radiating patch, and the microstrip feed line were modified. Other structural elements, such as the substrate's thickness (h) and permittivity (ϵ_r), remained unchanged As a result of the optimization process, the antenna model shown in Figure 1 was finally obtained, the dimensions of which are presented in Table 2. For the antenna model obtained in this way, a physical model of the antenna was created, the appearance of which is shown in Figure 2. For the final model of the proposed antenna, computer simulations and measurements were carried out to determine the values of the antenna's electrical parameters.

Table 2. Antenna Design Dimensions.

Symbol	Dimension (mm)
Lf	132,100
Wf	3,085
Wtat	4,444
Wtab	4,444
Wt	71,110
Ht	17,780
Lp	13,330
Le	44,000
Wpt	20,000
Lm	61,780
Hta	57,340
Wpb	11,110

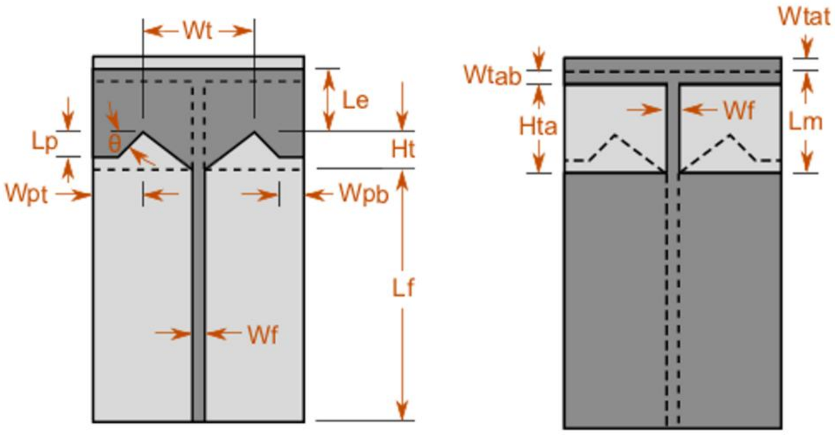

Figure 1. Developed model of DVB-T2 microstrip antenna with dimension markings – front view and rear view

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Figure 2. The view of completed DVB-T2 microstrip antenna: front view showing the radiating patch and microstrip feed line and rear view showing the ground plane.

3. Measurement Results for the Developed DVB-T2 Antenna

The proposed DVB-T2 antenna comprises three primary layers: the ground plane, the radiating element, and the dielectric substrate. Numerical simulations were performed using CST Microwave Studio, while experimental validation of the electrical parameters was conducted using a Rohde & Schwarz ZVA67 Vector Network Analyzer (VNA). The measurement setup for evaluating the reflection coefficient (S11) is illustrated in Figure 3. The simulations and measurements yielded electrical parameter values such as reflection coefficient, standing wave ratio, input impedance, antenna gain, and radiation characteristics. All of these parameters were compared to analyze the properties of the microstrip antenna.

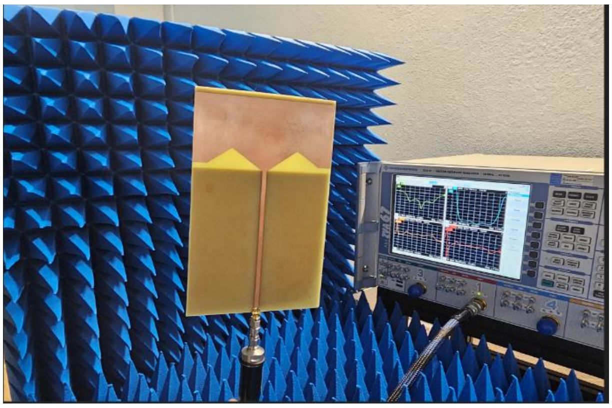

Figure 3. The view of the completed DVB-T2 microstrip antenna connected to the ZVA67 network analyzer during measurements.

3.1. Reflection Coefficient S_{11}

The first coefficient that allows us to determine the operating bandwidth of the proposed antenna is the reflection coefficient S11. Figure 4 presents its simulation and measurement results for the proposed DVB-T2 microstrip antenna. The proposed antenna resonates at a frequency of 620 MHz with a return loss of -27.19 dB. The proposed antenna has an operating bandwidth of 640 MHz, which gives a relative bandwidth of 103.22%. Based on this, we can conclude that this antenna can only be used in the selected band of the DVB-T2 system, i.e., the UHF band.

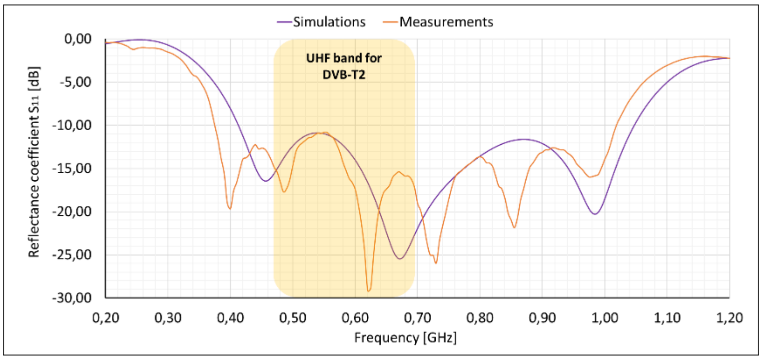

Figure 4. The value of the S_{11} reflection coefficient as a function of frequency for the proposed antenna model.

3.2. Voltage Standing Wave Ratio (VSWR)

Another parameter that determines the antenna's impedance properties is the voltage standing wave ratio (VSWR). For a microstrip antenna, the voltage standing wave ratio should not exceed 2 across the entire frequency band. Figure 5 shows the voltage standing wave ratio as a function of frequency. As can be seen, the VSWR value obtained at the resonant frequency of 620 MHz is 1.06, while the VSWR value of 2 was determined at frequencies of 380 MHz and 1.02 GHz, respectively. The above values indicate that the proposed antenna operates within the assumed DVB-T2 frequency band. The operating bandwidth of the proposed antenna covers all multiplex widths used in the UHF band in Poland.

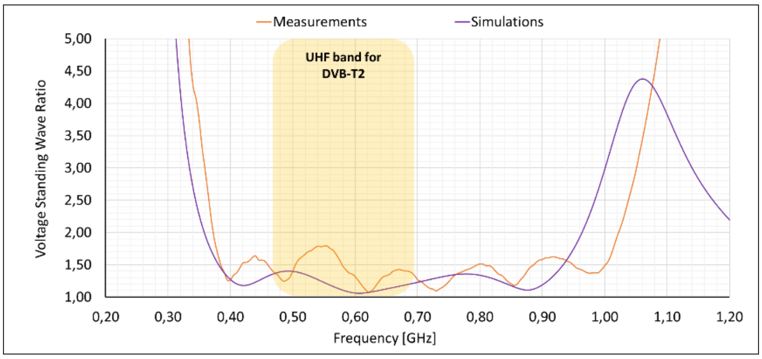

Figure 5. The value of the S11 reflection coefficient as a function of frequency for the proposed antenna model.

3.3. Input Impedance

The antenna's input impedance consists of real and imaginary parts, whose values vary with frequency. This assumed value should be considered when designing the antenna, as this can easily degrade its performance. The designed width and length of the antenna's feedline allowed for an input impedance of Z = 50.36 – j0.72 Ω at a resonant frequency of 620 MHz. At the extreme frequencies (0.38 GHz and 1.02 GHz) of the antenna's operating band, the input impedance is Z = 30.38 + j6.31 Ω and Z = 77.99 – j0.29 Ω, respectively. Detailed input impedance values for the proposed antenna as a function of frequency are shown in Figure 6.

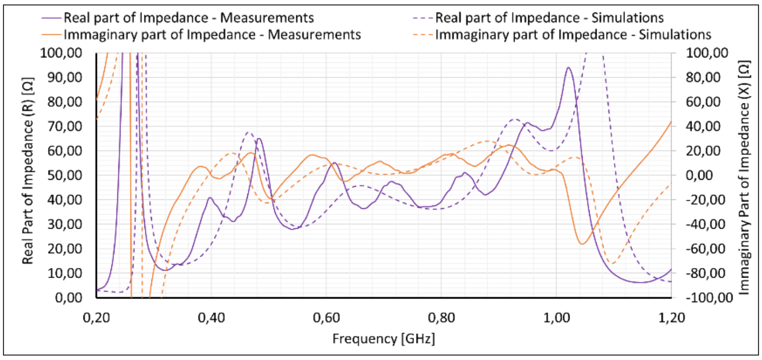

Figure 6. The input impedance value for the proposed antenna model.

3.4. Antenna Gain

One of the important parameters considered when designing the proposed microstrip antenna is energy gain, which should be as high as possible. The antenna's energy gain is given relative to an isotropic antenna and expressed in dBi units. The proposed antenna has a gain of 2.52 dBi at a resonant frequency of 620 MHz. This value is considered good for single-element microstrip antennas with omnidirectional characteristics, which is a significant achievement for this type of antenna design. This value was achieved thanks to the appropriate shape of the radiator. The energy gain versus frequency curve for the designed antenna is shown in Figure 7.

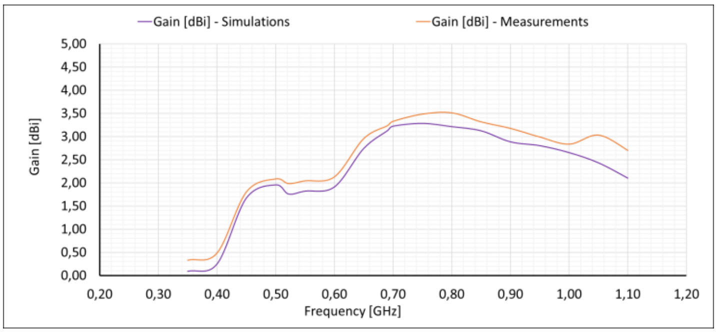

Figure 7. The value of the antenna gain for the proposed antenna model.

3.5. Radiation Patterns

The radiation pattern illustrates how the antenna radiates energy depending on the direction. It represents the normalized electric field distribution or the relative distribution of surface power density. The patterns are determined in two planes, horizontal and vertical, and can also be presented in three-dimensional form. Figure 8 shows the three-dimensional appearance of the radiation patterns of the proposed antenna for the selected multiplex frequencies: MUX1 – 650 MHz, MUX2 – 538 MHz, MUX3 – 522 MHz, MUX6 – 690 MHz. The antenna radiation patterns, along with the indicated energy gain, were obtained during simulations conducted in CST Microwave Studio software.

In the developed antenna model, the gain increases slightly with increasing frequency. At 522 MHz, a gain of 2.18 dBi was observed, while at 690 MHz, the gain was 3.22 dBi. The characteristics for each frequency appear very similar, suggesting that the changes are small in this frequency range.

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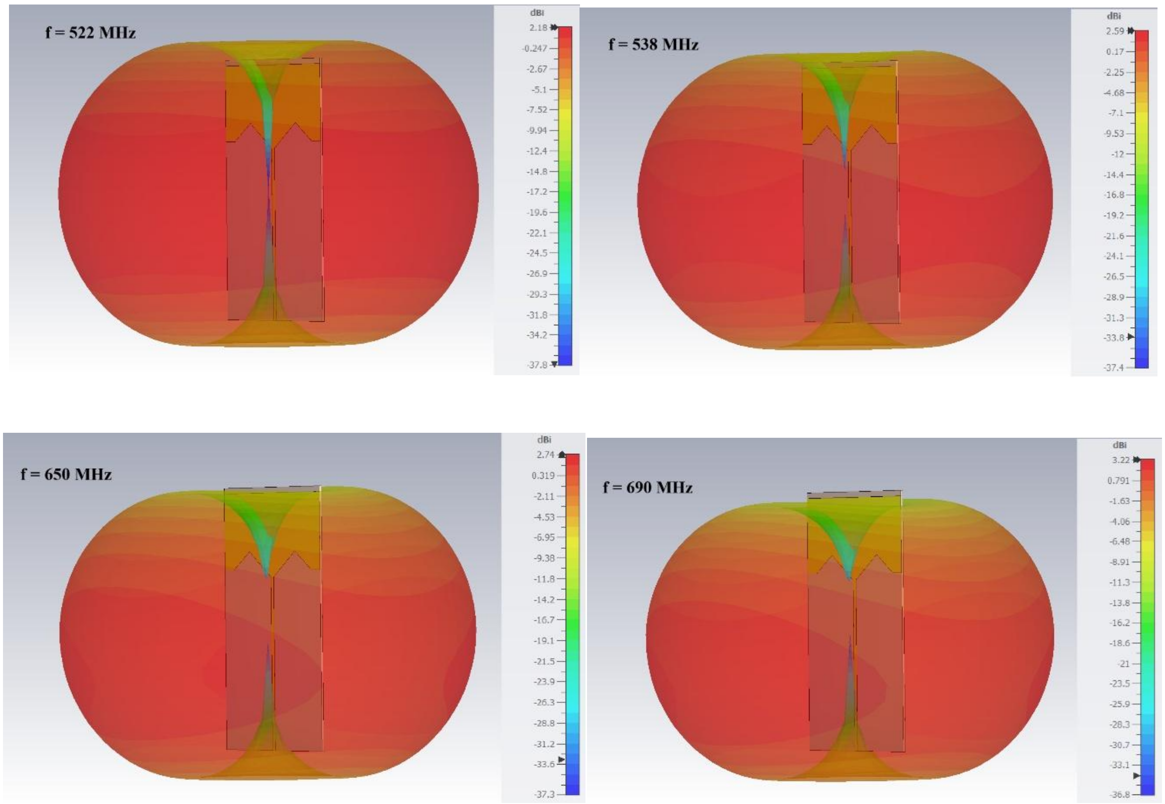

Figure 8. 3D radiation pattern of the designed DVB-T2 microstrip antenna for f = 522 MHz, f = 538 MHz, f = 650 MHz and f = 690 MHz.

4. Method of Measuring Selected Radio and Quality Parameters of the DVB-T2 System

The method of measuring selected radio and quality parameters of the DVB-T2 system using the PROMAX Ranger Neo Lite meter consisted in a comprehensive assessment of the signal at the reception site by analyzing its physical and digital properties, which enabled the determination of the transmission quality and its compliance with operational requirements. The purpose of the measurements was to ensure stable and error-free reception of television programs and to detect any interference, degradation of the antenna installation, or irregularities in the transmission path. Before starting the measurements, the antenna cable was connected to the meter's RF input, the connections were checked, the DVB-T2 mode was selected in the device menu, and the appropriate channel plan or frequency was set for the channel being tested. Next, it was necessary to wait for signal synchronization to be achieved, confirmed by the "LOCK" status, and in the case of multilayer transmission, select the appropriate PLP stream. Correct tuning of the meter to the carrier frequency was a prerequisite for obtaining reliable results, especially for C/N (Carrier-to-Noise Ratio) and MER (Modulation Error Ratio) measurements, as even slight detuning could lead to underestimation of quality parameters. Once stable synchronization was achieved, readings were taken of basic parameters, including signal strength, C/N ratio, MER, CBER, and LBER [12,13].

Signal power is the average power of the usable DVB-T2 signal within the occupied channel bandwidth and is typically expressed in dBm or dBμV. This parameter indicates the signal level reaching the receiver and directly impacts the quality of the received signal. Too low a level increases the impact of noise and interference, while too high a level can lead to input channel overload. The correct power range ensures optimal operation of the receiving system and forms the basis for further quality analysis.

Carrier-to-Noise Ratio (C/N) is defined as the ratio of the useful signal power to the noise power in the same band, expressed in decibels. This parameter determines the transmission's immunity to random interference and the influence of thermal and environmental noise. For each modulation and coding combination in the DVB-T2 system, there is a minimum C/N value, below which there is a rapid increase in bit errors and a loss of reception stability. A decrease in C/N is usually a direct result of signal attenuation, electromagnetic interference, or a deterioration in the quality of the antenna installation.

The MER (Modulation Error Ratio) is a measure of modulation quality and describes the ratio of the average power of ideal modulation symbols to the average error power of the modulation vector. This parameter indicates the degree of dispersion of constellation points relative to their theoretical positions. MER takes into account the combined effects of noise, interference, amplifier nonlinearity, phase errors, and multipath phenomena. A high MER value indicates "clean" modulation and a large margin of transmission quality, while a lower MER indicates signal degradation, even if the power level and C/N remain apparently correct. For this reason, MER is one of the most important indicators of DVB-T2 reception stability.

The Channel Bit Error Rate (CBER) measures the number of bit errors after OFDM demodulation and before LDPC/BCH error correction is applied. It is a measure of the "raw" quality of the radio path and directly reflects the impact of interference and noise on the transmission. High CBER values indicate that the error correction system is heavily loaded, which can lead to unstable receiver operation. CBER is particularly sensitive to pulse noise, channel interference, and momentary signal dropouts.

LBER (LDPC Bit Error Rate) is measured post-LDPC decoding and quantifies the residual errors remaining after primary error correction has been applied. This parameter is directly correlated with the perceived quality of video and audio reception. In a robust DVB-T2 system, the LBER should approach zero or fall below a threshold of , achieving what is known as Quasi-Error-Free (QEF) operation. An increase in LBER indicates that the correction capacity has been exceeded, resulting in visible artifacts, audio stuttering, or total signal loss.

Measurement results are interpreted in relation to the QEF (Quasi Error Free) criterion, which in the DVB-T2 standard denotes transmission virtually free of noticeable errors. Operation in QEF conditions is characterized by stable synchronization, very low LBER, and adequate C/N and MER margins. Achieving this condition guarantees correct reception of television services without any interference visible to the end user.

DVB-T2 quality parameters are closely interrelated. A decrease in signal power leads to a reduction in C/N, which results in a deterioration of MER and an increase in CBER, and consequently, an increase in LBER. Impulsive interference causes sudden increases in CBER, while path nonlinearities and multipath reflections most often manifest themselves in a decrease in MER. Therefore, a reliable assessment of signal quality should always include a simultaneous analysis of all parameters, not just individual values.

Regular measurements using the PROMAX Ranger Neo Lite meter enable ongoing monitoring of the antenna installation, detection of interference sources, assessment of broadcast quality, and prevention of failures. In installation and operational practice, these measurements are a fundamental diagnostic tool, ensuring stable operation of the DVB-T2 system and high quality of services provided.

5. Characteristics of Selected Antennas Used to Receive the DVB-T2 Signal

The development of digital terrestrial television in the DVB-T2 standard has led to increased requirements for the quality of the received signal and the stability of antenna installations. Unlike analog transmission, the digital system is characterized by a threshold nature of reception, meaning that even a slight deterioration in signal parameters can lead to a complete loss of image and sound. Therefore, the proper selection of a receiving antenna is one of the key elements ensuring the proper functioning of the DVB-T2 system.

Antennas used for digital terrestrial television reception vary significantly in their mechanical design, radiation patterns, antenna gain, operating bandwidth, and the inclusion of active amplification circuits. Depending on the local topography, distance from the transmitter, ambient interference levels, and the specific installation site, it is essential to select an antenna type that is precisely matched to the local RF environment.

This chapter describes the characteristics of selected antenna models used in DVB-T2 installations, both passive and active. It presents their construction, basic technical parameters, operation, and range of applications in practical installations. The aim of this chapter is to demonstrate the impact of proper antenna selection on signal reception quality and to facilitate choosing the optimal solution depending on local conditions.

Below, we present the characteristics of selected television antennas used for receiving DVB-T/T2 digital terrestrial television, along with a discussion of their construction, operating parameters, and typical applications in individual and community installations. The presented antennas, along with the developed microstrip DVB-T2 antenna, were used during the measurements conducted as part of the article.

5.1. DIPOL 3/21–48 Antenna

The DIPOL 3/21–48 antenna is a directional passive antenna designed for receiving signals in the UHF band (channels 21–48), manufactured and distributed by DIPOL. The antenna features a compact Yagi design consisting of a reflector, a dipole, and several directors, ensuring moderate gain in a small footprint. Its appearance is shown in Figure 9. Thanks to the small number of radiating elements, it is characterized by low wind load and easy installation on masts and balcony mounts. The antenna's typical gain is several decibels (approx. 7–9 dBi), making it suitable for operation in areas with moderate signal levels, and the front-to-back radiation ratio reaches 15–20 dB, effectively suppressing interfering signals from the rear of the antenna. It is characterized by a relatively narrow horizontal radiation angle of approximately 40–60°, which facilitates precise targeting of the transmitter. The structure is made primarily of aluminum and galvanized steel, ensuring weather resistance. The antenna does not have a built-in amplifier, but is equipped with a balun enabling direct connection of a coaxial cable. This antenna is often used in residential installations where the transmitter is relatively close and propagation conditions are favorable. The lack of a built-in amplifier reduces the risk of overload, but in weaker locations it may require the use of a masthead preamplifier.

Figure 9. The view of the DIPOL 3/21–48 antenna.

5.2. DIPOL 16/21–48 Antenna

The DIPOL 16/21–48 is an advanced directional Yagi antenna designed for the UHF band (channels 21–48). Shown in Figure 10, this model features a significantly higher number of directors compared to the 3/21–48, resulting in a superior gain of typically 12–15 dBi. The antenna's input impedance is 75 Ω, making it compatible with standard television installations. It features a very narrow radiation pattern and a high front-to-back ratio of approximately 20-25 dB, effectively reducing interference from unwanted directions. The construction is made of aluminum and corrosion-resistant steel components, ensuring durability in outdoor conditions. The antenna does not have a built-in amplifier, but is designed to work with an external mast-mount preamplifier. Its sophisticated design ensures excellent directivity and high rejection of signals from unwanted

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directions. This antenna is particularly recommended for receiving signals over long distances in areas with difficult propagation conditions, such as suburban, rural, or mountainous areas. Due to its larger size and weight, it requires a sturdy mounting. In installations with very low signal levels, it often works with a low-noise preamplifier.

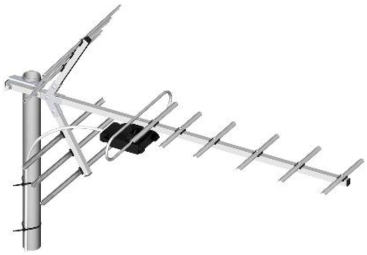

Figure 10. The view of the DIPOL 3/21–48 antenna.

5.3. TV Antenna with Amplifier SONUS – TV STVAC355

The SONUS STVAC355 TV antenna is a broadband antenna equipped with a built-in signal amplifier. This design is primarily intended for home use, both indoors and outdoors, depending on the mounting option. Its appearance is shown in Figure 11. The built-in amplifier compensates for losses caused by low signal levels and attenuation in coaxial cables. The typical gain of the active path ranges from several to over a dozen decibels, significantly improving reception in fringe areas. Thanks to its simple, compact design and minimal installation requirements, this antenna is widely used in apartments, single-family homes, and temporary installations. The amplifier is typically powered via an external power supply or a voltage inserter (power injector) connected to the signal path. However, the presence of the amplifier makes the antenna more susceptible to overloading in high-signal areas, which can degrade key quality parameters such as MER and BER.

Figure 11. The view of the SONUS – TV STVAC355 antenna.

5.4. Signal DA-3500L Antenna with Amplifier

The Signal DA-3500L antenna is a compact panel antenna designed for receiving DVB-T/T2 digital terrestrial television. It is manufactured under the Signal brand and distributed by DIPOL, among others. This design combines a flat, broadband antenna with a built-in signal amplifier, allowing it to be used both indoors and in sheltered outdoor locations.

The antenna features a compact panel housing constructed from weather-resistant materials. This design provides a wide beamwidth, making precise alignment less critical than with traditional Yagi antennas. The rear of the housing is equipped with an F-type coaxial connector and a DC power input (typically 5–12V) for the amplifier, which can be powered via an external power supply or directly from the tuner.

The integrated amplifier, with a gain of several to a dozen decibels, compensates for signal losses resulting from the antenna's low passive gain and cable attenuation. This allows the DA-3500L to receive signals in locations with moderate to weaker electromagnetic fields, such as urban apartments, lower floors, or locations far from windows. The antenna can be mounted on a desktop stand, wall-mounted, or with a small bracket, increasing installation flexibility. Its aesthetic, flat design is ideal for home applications where discreet antenna installation components are essential.

The main advantages of the Signal DA-3500L include its small size, easy installation, built-in amplifier, and the ability to operate in indoor mode. However, its relatively low passive gain is a limitation, meaning that in very weak signal conditions, this antenna may not provide stable reception. Furthermore, like other active antennas, it is susceptible to amplifier overload in areas with a strong signal, which can lead to reduced MER parameters and increased BER. In practice, the Signal DA-3500L antenna is primarily used in individual residential installations, as a solution for quick and easy DVB-T2 reception without the need for an external mast system. It is particularly useful in situations where installing a traditional roof antenna is impossible or uneconomical.

Figure 12. The view of the Signal DA-3500L antenna.

These antennas differ primarily in design and intended use. The DIPOL 3/21–48 and DIPOL 16/21–48 models are passive antennas with high parameter stability and low susceptibility to interference, with the 16/21–48 version providing significantly higher gain and better directivity. The SONUS TV STVAC355 and Signal DA antennas are active antennas with an amplifier, which allows them to be used in areas with weak signals, but at the same time increases the risk of quality degradation in strong signals.

The selection of an appropriate antenna type depends on the distance from the transmitter, terrain conditions, signal levels, and DVB-T2 reception stability requirements. In installations with favorable propagation conditions, passive antennas are recommended. Conversely, in peripheral areas, it is advisable to use antennas with an amplifier, provided that signal quality parameters are carefully monitored to prevent degradation.

6. Measurements and Analysis of Selected Radio and Quality Parameters of the DVB-T2 System

The rapid advancement of broadcasting technologies and increasing consumer demand for superior image and sound quality have led to the implementation of the DVB-T2 digital terrestrial television standard. Compared to its predecessor, DVB-T, this system offers enhanced spectral efficiency, superior robustness against interference, and the capacity to broadcast high-definition (HD) and even ultra-high-definition (UHD) content.

The proper functioning of the DVB-T2 system depends on many factors, including propagation conditions, transmitter parameters, the type of receiving antenna used, and the receiver's location. Therefore, detailed measurements of radio parameters and signal quality are an essential element of assessing transmission quality.

The purpose of this chapter is to present the measurement results of selected DVB-T2 system parameters, such as signal level, MER, signal-to-noise ratio, and transmission error rate. Analysis of the obtained results allows for the assessment of reception quality in various field conditions and the determination of the actual operational capabilities of the tested system..

The measurements were taken in selected locations in Warsaw and its surrounding areas using the antennas described in the article, which allowed for a comparison of signal parameters in urban and suburban environments. The obtained results provide the basis for drawing conclusions

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regarding the effectiveness of the DVB-T2 system and the quality of digital terrestrial television reception in the studied area.

Figure 13 shows a diagram of the measurement setup used to test the radio and quality parameters of the DVB-T2 system. The basic element of the system is a television transmitter, which emits a radio signal towards terrestrial receivers. The broadcast signal is received by the antenna under test, placed on a stable tripod. This antenna is connected via a coaxial cable to a signal analyzer (PROMAX), which allows for the measurement of key transmission parameters. The signal analyzer is used to determine, among other things, the signal level, MER (Modulation Error Ratio), signal-to-noise ratio (C/N), bit error rate (BER), and DVB-T2 signal reception quality.

This setup allows for measurements to be performed in field conditions that closely resemble the actual operating conditions of receiving antennas. The station's appearance during measurements at selected measurement points is shown in the photos in Figure 14.

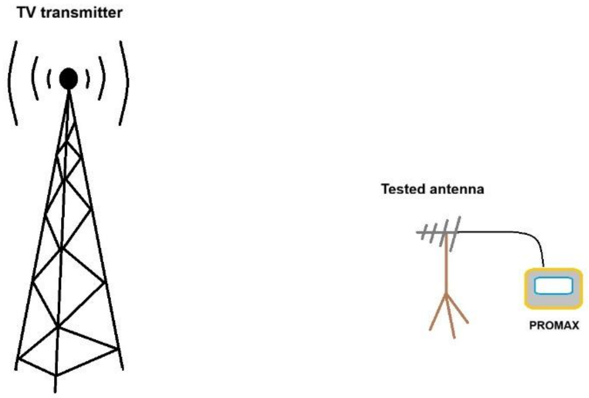

Figure 13. Diagram of the measurement station.

Figure 14. The view of the measuring station during the measurements.

Figure 15 shows the distribution of selected measurement points located in and around Warsaw. These points were placed in various directions and distances from the main transmitters, which allows for the assessment of signal quality in various propagation conditions. Selecting multiple locations allows for: analyzing the effect of distance from the transmitter on signal parameters, assessing the impact of terrain and development, comparing reception quality in urban and suburban areas, and determining signal stability in various environmental conditions.

The arrangement of measurement points allows for obtaining representative results, reflecting the actual conditions of DVB-T2 terrestrial television reception in the tested area.

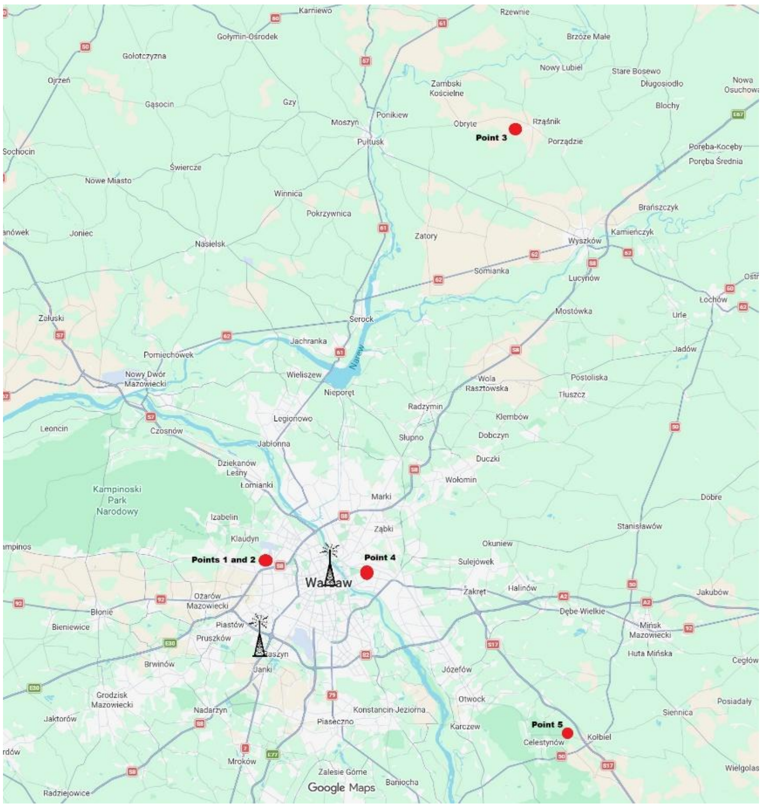

Figure 15. Location of selected measurement points around Warsaw.

To receive a DVB-T2 digital television signal, depending on the distance to the transmitter, the antenna types typically used are as shown in Table 1. During the tests, antennas designed for operation in conditions similar to those of the proposed antenna were used. The parameters of the tested antennas are given in Table 4.

Table 4. Basic parameters of the antennas used in the research.

Symbol	Antenna name	Gain
WAT	DVB-T2 microstrip antenna	3.22 dBi
WAT power	DVB-T2 microstrip antenna with amplifier	26 dBi
Signal	Signal DA-3500L Panel Antenna with Amplifier	21 dBi
Sonus	Sonus indoor antenna – TV STVAC355 with amplifier	40 dBi
Dipol 16	Directional Dipole Yagi Antenna 16/21-48	12 dBi
Dipol 3	Directional Dipole Yagi Antenna 3/21-48	5 dBi

The best measure of received signal quality is subjective – our eyes and ears. However, when installing an antenna system, objective measures such as received signal strength and quality should also be considered. This allows for the selection of the optimal antenna system solution. The minimum received radio signal power required to properly receive a television broadcast depends on the sensitivity of the television receiver; on average, it is approximately 19 dBuV (-90 dBm). Adequate power does not always guarantee proper reception, therefore, signal quality is also an important parameter, objectively described by measures such as Bit Error Ratio (BER), Modulation Error Ratio (MER), and Carrier to Noise Ratio (CNR). The most interesting quality measure for digital television signals is MER. For stable television reception, the MER value should be higher than 12 dB. A MER value close to 30 dB indicates very good signal quality. The MER value depends on the received signal strength and the CNR value.

The measuring device provided the MER value only when the received signal value was greater than 35 dBuV and the CNR value was greater than 24 dB, in other cases the meter did not measure this parameter.

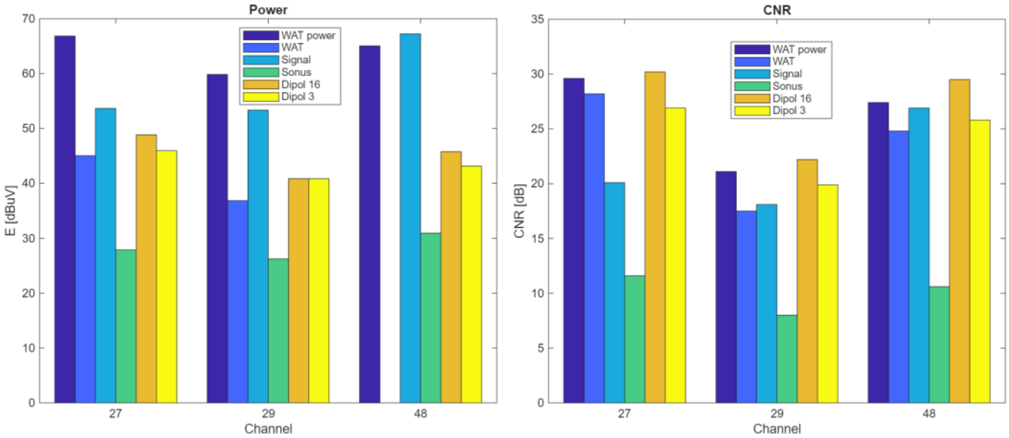

Figure 17. Measured values of the received signal power and CNR for the receiver location in an urban area approx. 8-10 km from the transmitter (Point 4).

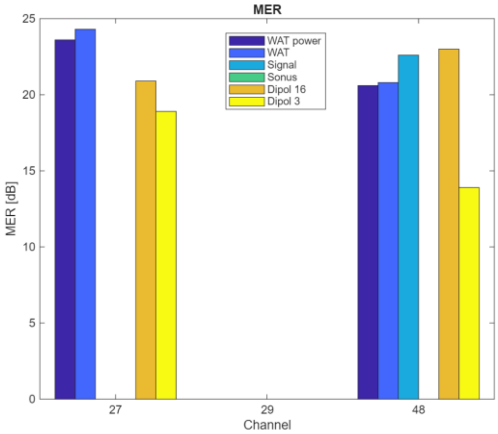

Figure 18. Measured MER values for the receiver location in an urban area approx. 8-10 km from the transmitter (Point 4).

At the Gocław location, all antennas except the Sonus antenna provided reception of MUX3 and MUX6. MUX2 was not received despite high signal strength. For both received multiplexes, only the WAT antenna with an additional amplifier provided artifact-free reception (Figure 18).

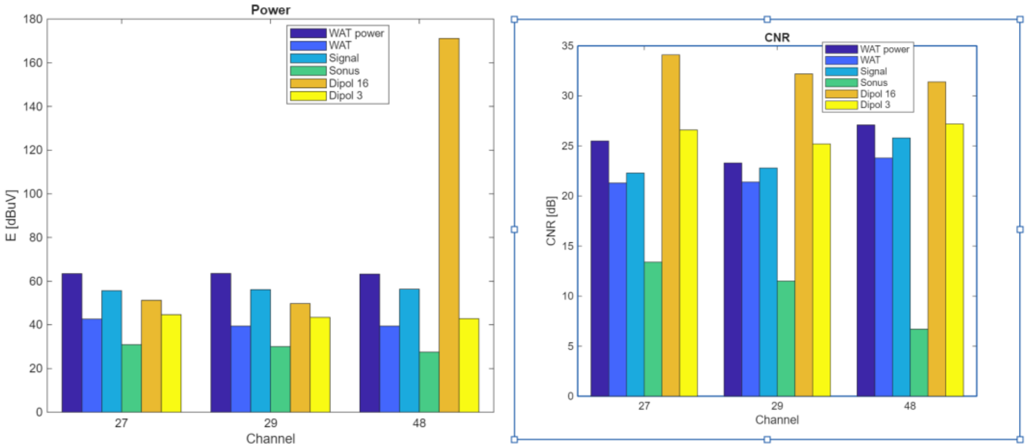

Figure 19. Measured values of the received signal power and CNR for the receiver location in a rural area approx. 34-38 km from the transmitter (Point 5).

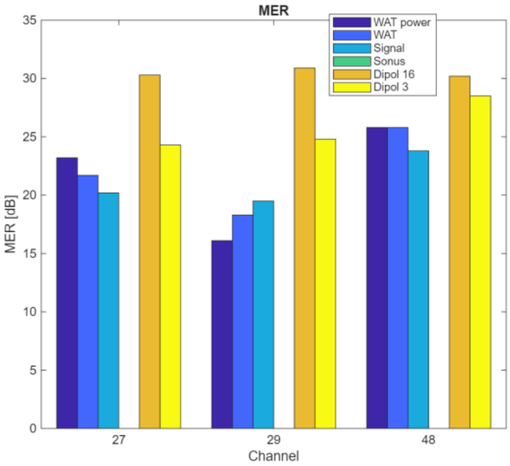

Figure 20. Measured MER values for the receiver location in a rural area approximately 34-38 km from the transmitter (Point 5).

At the BOCIAN location, the received signal strength and CNR value indicate the possibility of receiving the TV signal on all channels by most antennas, except the Sonus antenna.

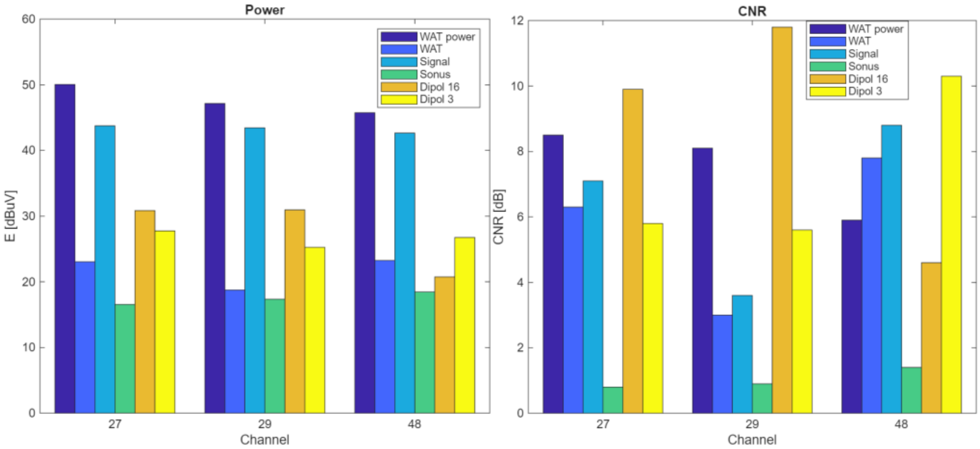

Figure 21. Measured values of received signal power and CNR for locations at distances above 50 km (MER and LBER values were not measured by the meter; Point 3).

Table 5. TV reception possible - measured LBER better than $10^{-6.}$

Localization	Channel	WAT Power	WAT	Signal	Sonus	Dipol 16	Dipol 3
Point 1	**27**	YES	YES	YES	NO	YES	YES
	29	NO	NO	NO	NO	YES	NO
	48	YES	YES	YES	NO	YES	YES
Point 2	**27**	YES	YES	YES	NO	YES	YES
	29	YES	YES	YES	YES	YES	YES
	48	YES	YES	YES	NO	YES	YES
Point 3	**27**	NO	NO	NO	NO	NO	NO
	29	NO	NO	NO	NO	NO	NO
	48	NO	NO	NO	NO	NO	NO
Point 4	**27**	YES	YES		NO	YES	YES
	29	NO	NO	NO	NO	NO	NO
	48	YES	YES	YES	NO	YES	YES
Point 5	**27**	YES	NO	YES	NO	YES	YES
	29	YES	YES	YES	NO	YES	YES
	48	YES	YES	YES	NO	YES	YES

During measurements conducted at a distance exceeding 50 km, none of the tested antennas achieved television signal reception. The highest signal strength was provided by the WAT and Signal panel antennas, both equipped with amplifiers.

At urban locations approximately 10 km from the transmitter, television signal reception was achieved by all antennas with the exception of the Sonus antenna. Both WAT antenna configurations delivered artifact-free reception.

The measurements demonstrate that the proposed WAT antenna provides high signal quality at both near and mid-range locations, provided it is paired with an appropriate amplifier. This antenna serves as a viable alternative to commonly used models for distances of up to 50 km from the transmitter.

The tests were carried out in a network of transmitters operating in the SFN (Single Frequency Network) mode with the power of transmitters in Raszyn and Warsaw Palace of Culture and Science, respectively: 130 kW and 10 kW on channel 27, 100 kW and 3 kW on channel 29, 100 kW and 12 kW on channel 48.

7. Conclusions

This article presents a comprehensive study encompassing the design, simulation, fabrication, and experimental verification of a microstrip antenna designed for DVB-T2 digital terrestrial television reception in the UHF band. The work is interdisciplinary, combining antenna theory, radio wave propagation, radio measurements, and practical aspects of receiver system installation.

In the initial stage of the work, an analysis was conducted regarding the requirements for antennas used in the DVB-T2 system in Poland, with a particular focus on frequency ranges, modulation parameters, and propagation conditions. Based on these findings, a microstrip antenna operating in the UHF band was designed, fabricated on an FR4 laminate with a thickness of 1.6 mm and a dielectric permittivity of $\epsilon r=4.4$. The dimensions used resulted in a compact design, suitable for integration with terminal devices.

The design process was supported by electromagnetic simulations performed in the CST Microwave Studio environment, which enabled the optimization of antenna parameters such as the reflection coefficient, impedance matching, operating bandwidth, gain, and radiation patterns. As a result of the optimization, an antenna was obtained with a resonance at a frequency of approximately 620 MHz, a wide operating bandwidth of 640 MHz, and excellent impedance matching.

Subsequently, a physical prototype of the antenna was fabricated, and laboratory measurements were conducted using a Rohde&Schwarz ZVA67 network analyzer. The measurement results confirmed high correlation with the simulation data, demonstrating the validity of the adopted design methodology. A low reflection coefficient (–27.19 dB) was achieved, along with a Voltage Standing Wave Ratio (VSWR) below 2 across the entire operating bandwidth, and a gain reaching 3.22 dBi.

The next stage of the work involved field measurements of the radio and quality parameters of the DVB-T2 system using the PROMAX Ranger Neo Lite meter. The studies were conducted at several locations in and around Warsaw, representing various propagation environments: urban, suburban, and areas distant from the transmitter. The measurements utilized both the designed microstrip antenna and four commercial antennas of different designs.

The analysis included measurements of signal strength, C/N ratio, MER, CBER, and LBER, which allowed for a comprehensive assessment of transmission quality. The obtained results enabled a comparison of the effectiveness of individual antennas in real-world operating conditions and an assessment of their suitability in various application scenarios.

The study demonstrated that transmitter distance, antenna mounting height, and antenna design significantly impact DVB-T2 reception quality. Notably, the MER and LBER parameters proved to be the most reliable indicators of reception stability.

The research conducted as part of this work confirms that the designed microstrip antenna for DVB-T2 reception in the UHF band meets all design requirements, regarding both electrical parameters and functional properties. The reflection coefficient, impedance matching, and antenna gain values obtained from simulations and laboratory measurements validate the adopted design methodology and the effectiveness of the model optimization performed in CST Microwave Studio. The high correlation between simulation results and measurements conducted with a Vector Network Analyzer (VNA) confirms the reliability of the proposed model and the precision of the fabrication process.

Field measurement results demonstrated that the developed antenna, particularly when paired with an additional amplifier, ensures stable DVB-T2 reception at distances up to approximately 50 km from the transmitter. Quality parameters such as MER, C/N, and LBER reached levels consistent with Quasi-Error-Free (QEF) operation, resulting in an absence of visible image or sound artifacts. In direct comparison with commercial directional antennas, the designed structure demonstrated competitive reception performance while maintaining significantly more compact dimensions.

A comparative analysis of different antenna types confirmed that design and gain significantly impact signal stability. Multi-element passive high-gain antennas demonstrated superior performance under challenging propagation conditions. In contrast, active antennas, despite their high gain, were more susceptible to overload and the subsequent degradation of quality parameters. The poorest results were recorded for the indoor antenna, whose effectiveness was highly dependent on mounting height and local environmental factors.

The results clearly demonstrate that received signal strength alone is an insufficient criterion for assessing digital transmission quality. Quality parameters—specifically MER and LBER—are crucial, as they directly reflect the system's interference immunity and the stability of data stream decoding. A reduction in C/N levels leads to a deterioration of MER and a subsequent increase in bit errors, confirming a strong correlation between the analyzed metrics.

Antenna placement and mounting height also proved to be significant factors influencing reception quality. Raising the antenna above obstacles, such as urban buildings or vegetation, significantly improved signal quality metrics. This highlights the importance of considering site-specific propagation conditions when designing and installing DVB-T2 reception systems.

In summary, the designed DVB-T2 microstrip antenna provides an effective, compact, and competitive solution for digital terrestrial television reception in the UHF band. Its electrical properties and field test results confirm its practical applicability for both individual installations and integrated receiver systems. The obtained results also provide a foundation for future development, including further design optimization, the use of materials with lower dielectric losses, and integration with active amplification systems.

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Abbreviations

The following abbreviations are used in this manuscript:

DVB-T2	(Digital Video Broadcasting — Second Generation Terrestrial
MFN	Multi-Frequency Network
SFN	Single Frequency Network
NLOS	Non-Line-of-Sight
OFDM	Orthogonal Frequency Division Multiplexing
MUX	Multiplex
C/N	Carrier-to-Noise Ratio
MER	Modulation Error Ratio
CBER	Channel Bit Error Rate
LBER	LDPC Bit Error Rate
QEF	Quasi Error Free
BER	Bit Error Rate

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