

Analysis of Ergodic Capacity for TV 3.0

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Abstract—Television (TV) 3.0 introduces advanced physical-layer technologies to support next-generation digital terrestrial television services, including high-definition and ultra-high-definition video delivery. Among these technologies, dual-polarized 2×2 multiple-input multiple-output (MIMO) transmission plays an important role in improving spectral efficiency, but its performance is strongly affected by propagation conditions, terrain characteristics, and polarization coupling. This work analyzes the ergodic capacity of a TV 3.0 link under realistic propagation assumptions. The proposed simulation framework combines a dual-polarized MIMO channel model with geographic information, including digital elevation data, land cover classification, line-of-sight characterization, and path-loss prediction based on ITU-R P.1812. Monte Carlo simulations are performed to estimate capacity maps over representative broadcasting sites in Brasília, Brazil. The analysis considers different frequency bands allocated to TV 3.0, transmit power levels, and reception conditions, with emphasis on average capacity, capacity percentiles, and the probability of meeting target data-rate requirements for video services. The proposed approach provides a spatially detailed assessment of TV 3.0 coverage and capacity, supporting the evaluation of deployment trade-offs related to frequency selection, transmit power, and service availability.

Keywords—Broadcasting, TV 3.0, Capacity.

I. INTRODUCTION

Since the early 2000s, the Brazilian television broadcasting system has undergone a gradual transformation to meet increasingly stringent quality-of-service (QoS) requirements. The adoption of the integrated services digital broadcasting – terrestrial version B (ISDB-TB) standard in 2006 marked the introduction of digital terrestrial television broadcasting (DTTB) in Brazil [1]. It started the transition, commonly referred to as TV 2.0, from legacy analog systems to digital television. Due to the technical and logistical challenges of implementing a nationwide transition in a country on continental-scale, the analog switch-off was only completed in December 2025 [2]. Throughout this extended transition period, several enhancements to DTTB were developed, introducing new functionalities aimed at improving audiovisual quality and user interaction [3]. This evolutionary stage, often referred to as TV 2.5, extends the capabilities of TV 2.0 while maintaining full backward compatibility.

Looking ahead, the Brazilian digital terrestrial television system forum (SBTVD) has been leading the definition of requirements and the evaluation of candidate technologies

for the next generation of DTTB, known as TV 3.0 or DTV+ [3]. After multiple evaluation phases covering the physical layer (PL), transport layer (TL), audio/video coding (A/V), and application coding (AppC), with contributions from several international stakeholders; the forum selected the advanced television systems committee (ATSC) 3.0 standard as the primary reference for the PL in TV 3.0 [3]–[5].

One of the key features of the latest version of ATSC 3.0 is the adoption of dual-polarized 2×2 multiple-input multiple-output (MIMO) to increase spectral efficiency and support the high data rates required for ultra-high definition (UHD) content delivery [6]. In this configuration, both ends of the communication link are equipped with dual antennas employing orthogonal polarization states, typically horizontal and vertical polarizations, thereby enabling spatial multiplexing over the same frequency band [7]. TV 3.0 is expected to operate within the frequency bands of 174–216 MHz, 231–237 MHz, 250–295 MHz, 345–363.5 MHz, and 470–698 MHz, with a channel bandwidth of 6 MHz [4], [8]. To further improve spectral efficiency, the use of Layered Division Multiplexing (LDM) has been proposed. In this technique, multiple service layers are transmitted simultaneously within the same frequency band, each employing distinct power levels and signal configurations, thereby enabling the coexistence of services with different robustness and data rate requirements [9]. A total of six modulation schemes are supported, including uniform quadrature phase shift keying (QPSK) and six non-uniform constellations, spanning modulation orders from 16-quadrature amplitude modulation (QAM) to 1024-QAM [3].

Among the technical requirements of TV 3.0, the channel capacity must be sufficient to support 1080p video with quality equal to or exceeding that achieved in TV 2.5, in addition to enabling 8K UHD (4320p) content. In terms of data rate, the system is expected to support a range from 1 Mbps to 57 Mbps to accommodate multiple services [10]. For proper operation of the physical layer, the required signal-to-noise ratio (SNR) spans from -6.2 dB to 36 dB [10].

Due to the importance of evaluating the performance of TV 3.0 to ensure the quality requirements of next-generation broadcasting systems, several academic studies have investigated different aspects of this technology. A systematic overview of TV 3.0 is presented in [3], where its main technical features are highlighted, including the PL, TL, A/V, and AppC. The requirement for 2×2 MIMO operation with dual polarization in the PL of TV 3.0 has raised concerns about mutual interference between polarizations, commonly referred to as cross-polarization interference (XPI). In [11], [12], measurement results obtained with ATSC 3.0 compatible equipment are presented, evaluating the impact of XPI on the carrier-to-noise (C/N) ratio of the system. The results

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indicate that this effect remains significant even in scenarios with relatively high cross-polarization discrimination (XPD). In [13], different reception metrics are analyzed through both measurements and simulations of a TV 3.0-based system under the influence of XPI. The results show that the degradation of the electromagnetic wave vector under urban and indoor environments is considerable, impairing the orthogonality of the signal components required for proper MIMO operation. In [14], performance results obtained from field measurements conducted in the city of Rio de Janeiro are presented, using an ATSC 3.0 signal in a 2×2 MIMO configuration. The results indicate an increase in reception errors for C/N below 26 dB. Overall, the findings suggest that ATSC 3.0 provides adequate performance concerning practical deployment scenarios and varying mobility conditions.

Despite the important contributions of previous studies, existing analyses of TV 3.0 systems are generally restricted to controlled experiments or limited field measurements, which do not fully capture the impact of realistic propagation conditions on system performance. This reveals a gap in the performance evaluation of TV 3.0 systems under complex and realistic conditions. To address this gap, this work evaluates the ergodic capacity of a TV 3.0 link using 2×2 dual-polarized MIMO simulations. The proposed approach combines ITU-R P.1812 path-loss prediction, digital elevation data, land-cover classification, and LoS/NLoS characterization to perform capacity analysis under realistic deployment scenarios

Notation Remarks: Lowercase bold letters denote vectors, while uppercase bold letters denote matrices. The complex Gaussian distribution with mean μ and variance σ^2 is represented as $\mathcal{CN}(\mu, \sigma^2)$. The uniform distribution in the range $[a, b]$ is denoted as $\mathcal{U}(a, b)$. The expected value operator is represented as $\mathbb{E}[\cdot]$. The Hadamard product between matrices is denoted by $\mathbf{A} \odot \mathbf{B}$. The matrix determinant and conjugate transpose are denoted as $\det(\cdot)$ and $(\cdot)^H$, respectively.

II. SYSTEM MODEL

The TV 3.0 link is modeled as a 2×2 dual-polarized MIMO channel, in which a base station (BS) is equipped with two antennas that transmit to a receiving unit, also equipped with two antennas, where one antenna transmits (or receives) in horizontal polarization and the other transmits (or receives) in vertical polarization, as illustrated in Fig. 1. In this context, the received signal vector, denoted as $\mathbf{y} \in \mathbb{C}^{2 \times 1}$, is given by

$$\mathbf{y} = \mathbf{H}\mathbf{x} + \mathbf{n} = \begin{bmatrix} h_{HH} & h_{HV} \\ h_{VH} & h_{VV} \end{bmatrix} \mathbf{x} + \mathbf{n}, \quad (1)$$

where $\mathbf{H} \in \mathbb{C}^{2 \times 2}$ is the channel matrix, with co-polarization coefficients h_{HH} and h_{VV} and cross-polarization terms h_{HV} and h_{VH} ; $\mathbf{x}$ is the transmitted symbol vector with $\mathbb{E}[\|\mathbf{x}\|^2] = P_t$, with P_t denoting the maximum transmitted power; and $\mathbf{n} \in \mathbb{C}^{2 \times 1}$ is the additive white Gaussian noise vector with components distributed as $\mathcal{CN}(0, \sigma_n^2)$, with σ_n^2 denoting the noise variance.

The channel matrix $\mathbf{H}$ is characterized as [15]

$$\mathbf{H} = \sqrt{\beta} \left(\sqrt{\frac{K}{K+1}} \tilde{\mathbf{H}} \odot \mathbf{P}(\bar{\chi}) + \sqrt{\frac{1}{K+1}} \tilde{\mathbf{H}} \odot \mathbf{P}(\tilde{\chi}) \right), \quad (2)$$

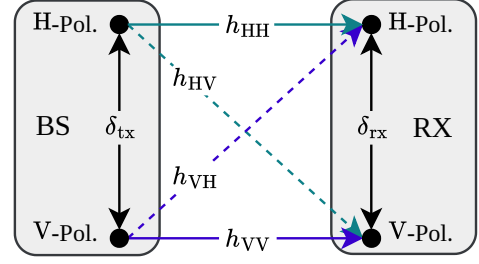


Fig. 1. Dual polarization TV 3.0 MIMO channel.

in which β is the distance-dependent path loss, $\tilde{\mathbf{H}} \in \mathbb{C}^{2 \times 2}$ is the small-scale fading matrix, whose components are $\mathcal{CN}(0, 1)$ distributed random variables; and $\tilde{\mathbf{H}}$ is the line-of-sight (LoS) components matrix, with elements given by

$$[\tilde{\mathbf{H}}]_{m,n} = e^{-j \frac{2\pi}{\lambda} [(m-1)\delta_{tx} \sin(\theta_{tx}) + (n-1)\delta_{rx} \sin(\theta_{rx})] + j\varphi_0}, \quad (3)$$

where m and $n \in [1, 2]$ are the antenna elements indices, λ is the wavelength, θ_{tx} is the angle-of-departure (AoD), θ_{rx} is the angle-of-arrival (AoA), δ_{tx} and δ_{rx} are the spacing between the elements of the transmitting and receiving antennas, respectively; and $\varphi_0 \sim \mathcal{U}(-\pi, \pi)$ is a random phase term. The value K in (2) is the Rice factor, which characterizes the ratio between the LoS power and the scattered power.

Finally, $\mathbf{P}(\bar{\chi}) \in \mathbb{R}^{2 \times 2}$ and $\mathbf{P}(\tilde{\chi}) \in \mathbb{R}^{2 \times 2}$ are used to characterize the polarization mismatch losses, with $\bar{\chi}$ and $\tilde{\chi}$ being the XPDs at the LoS and scattered terms of the MIMO channel, respectively. $\mathbf{P}(x)$ is generically expressed by

$$\mathbf{P}(x) = \begin{bmatrix} \sqrt{\frac{x}{x+1}} & \sqrt{\frac{1}{x+1}} \\ \sqrt{\frac{1}{x+1}} & \sqrt{\frac{x}{x+1}} \end{bmatrix}. \quad (4)$$

The XPD of the LoS channel depends fundamentally on the polarization and alignment properties of the antennas in the link. On the other hand, the XPD of the scattered part of the channel depends on the depolarizing effects that occur along the electromagnetic interactions with the medium. To capture these effects, the XPD terms in dB are modeled as $\bar{\chi} \sim \mathcal{N}(\mu_{\bar{\chi}}, \sigma_{\bar{\chi}}^2)$ and $\tilde{\chi} \sim \mathcal{N}(\mu_{\tilde{\chi}}, \sigma_{\tilde{\chi}}^2)$, where $\mu_{\bar{\chi}}$ and $\mu_{\tilde{\chi}}$ are the mean values, and $\sigma_{\bar{\chi}}^2$ and $\sigma_{\tilde{\chi}}^2$ are the variances [16].

A. Capacity Analysis

In this work, we assume a scenario where the MIMO channel is known only at the receiver, but not at the transmitter. Given that the channel state information (CSI) is not known at the transmitter, we assume that the BS divides the power equally between the two transmitting antennas. Therefore, the ergodic capacity of the channel, in bits/s, is calculated as [17]

$$\bar{C} = \mathbb{E} \left[B_w \log_2 \det \left(\mathbf{I}_2 + \frac{P_t}{2\sigma_n^2} \mathbf{H} \mathbf{H}^H \right) \right], \quad (5)$$

in which B_w is the system bandwidth and $\mathbf{I}_2$ is the 2×2 identity matrix. The expected value in (5) is calculated using Monte Carlo simulations, under multiple channel evaluations, as discussed in Subsection II-B.

B. Simulation Methodology

The simulations follow a methodology based on [18], which uses real geographic data to characterize the large-scale parameters of the channel. For this purpose, digital elevation models (DEMs) from the National Aeronautics and Space Administration (NASA) Shuttle Radar Topography Mission (SRTM) are applied. By processing the GeoTIFF¹ files in this dataset, it is possible to access the terrain elevation profiles across the Brazilian territory at a maximum spatial resolution of 30 m $\times$ 30 m. For a particular case of study, the region of interest is defined as a square area of area $L_d \times L_d$ km² centered on the BS coordinates, denoted as $\mathbf{p}_{\text{tx}}$; and discretized into a $N_a \times N_a$ grid. The receiving points are distributed on the grid, with each point indexed as (i, j) , where $i, j \in [1, \dots, N_a]$. The BS itself is positioned at the center pixel, indexed as $(N_a/2, N_a/2)$. The height above the ground of the receivers is assumed constant and is denoted as h_{rx} . In this configuration, a total of N_a^2 links can be characterized, each with a channel matrix as expressed in (2).

The simulations are based on two heat maps defined over the region of interest. The first map characterizes the LoS condition at pixel (i, j) , denoted by $\mathbf{L}(i, j)$, while the other one represents the path loss at position (i, j) , denoted as $\mathbf{B}(i, j)$, respectively. The LoS map $\mathbf{L}(i, j)$ is obtained using a simplified geometric approach based exclusively on the topography of the terrain. Specifically, if the LoS component of the link at position (i, j) is obstructed by terrain features, the link is classified as non-LoS (NLoS), and we set $K = 0$ and $\mathbf{L}(i, j) = 0$. Otherwise, the link is considered to have a LoS component, and $\mathbf{L}(i, j) = 1$. For links classified as LoS, the Rician K -factor is determined using the model in [19] as

$$K = \frac{P_{\text{LoS}}(d)}{1 - P_{\text{LoS}}(d)}, \quad (6)$$

where $P_{\text{LoS}}(d)$ denotes the probability of LoS as a function of the link distance d . For a given region, the function $P_{\text{LoS}}(d)$ can be estimated directly from the LoS map $\mathbf{L}(i, j)$, since each coordinate (i, j) is associated with a specific distance to the BS. By grouping points according to their distance, the empirical LoS probability can be computed for each distance value, thereby yielding the $P_{\text{LoS}}(d)$ curve for the region.

The calculation of the path loss map $\mathbf{B}(i, j)$ is done based on the model presented in ITU-R Recommendation ITU-R P.1812-4 [20]. The model is able to incorporate frequency-dependent parameters, field polarization, terrain profiles, antenna characteristics, land cover classification, and radio-climatic zoning to produce field strength predictions with high spatial resolution. To apply this recommendation, it is necessary to determine the type of land cover to classify each point on the grid as water/sea, open/rural, suburban, urban/trees/forest, and dense urban. Thus, we applied the methodology proposed in [21], which combines cross-referenced data from different databases to classify land cover.

To evaluate system performance, we adopt a Monte Carlo-based methodology with N independent channel realizations. In each realization, the small-scale fading parameters

are randomly generated, which yields a new instance of the channel matrix $\mathbf{H}$ for a given position (i, j) . For each realization, the corresponding instantaneous capacity is computed. The ergodic capacity at position (i, j) is then estimated as the sample mean over N instantaneous capacity values. At the end of this process, an ergodic capacity map $\mathbf{C}(i, j)$ is obtained. Algorithm 1 summarizes the simulation methodology.

Input: $P_t, \mathbf{p}_{\text{tx}}, L_d, N_a, \delta_{\text{rx}}, \delta_{\text{tx}}, \mu_{\bar{\chi}}, \sigma_{\bar{\chi}}^2, \mu_{\tilde{\chi}}, \sigma_{\tilde{\chi}}^2, B_w$
Result: $\mathbf{C}(i, j)$

- 1 Compute $\mathbf{L}(i, j)$ and $\mathbf{B}(i, j)$;
- 2 Compute $P_{\text{LoS}}(d)$ from $\mathbf{L}(i, j)$;
- 3 Compute σ_n^2 ;
- 4 **for** $i \in N_a$: **do**
- 5 **for** $j \in N_a$: **do**
- 6 Get $\beta = \mathbf{B}(i, j)$;
- 7 Generate $\bar{\chi}$ and $\tilde{\chi}$;
- 8 Compute $\mathbf{P}(\bar{\chi})$ and $\mathbf{P}(\tilde{\chi})$;
- 9 **if** $\mathbf{L}(i, j) = 0$ **then**
- 10 $K = 0$
- 11 **else**
- 12 Compute K based on (6);
- 13 Compute θ_{tx} and θ_{rx} ;
- 14 **end**
- 15 Generate φ_0 and compute $\bar{\mathbf{H}}$;
- 16 **for** $n \in N$: **do**
- 17 Generate $\tilde{\mathbf{H}}$;
- 18 Compute $\mathbf{H}$;
- 19 Compute
- 20 $C_n = B_w \log_2 \det \left(\mathbf{I}_2 + \frac{P_t}{2\sigma_n^2} \mathbf{H} \mathbf{H}^H \right)$;
- 21 **end**
- 22 Compute $\bar{C} = \frac{1}{N} \sum_{n=1}^N C_n$;
- 23 $\mathbf{C}(i, j) = \bar{C}$
- 24 **end**
- 25 **end**
- 26 **return** $\mathbf{C}(i, j)$;

Algorithm 1: Algorithm for computing $\mathbf{C}(i, j)$.

III. NUMERICAL RESULTS

The results presented in this section are based on the aggregation of capacity maps generated for 10 different sites, whose coordinates and antenna heights were extracted from the Mosaico platform of the National Telecommunications Agency (Anatel) [22], as presented in Table I. All sites are located within the territory of Brasília, Federal District, Brazil. Each site covers a lateral extent of approximately $L_d \approx 444$ km (corresponding to 4° in both latitude and longitude) in the grid with 360×360 pixels ($N_a = 360$), resulting in 129600 samples per simulation. The antenna element spacing is assumed to be $\delta_{\text{tx}} = \delta_{\text{rx}} = \lambda/2$. The XPD statistics are fixed as $\mu_{\bar{\chi}} = 14.7$ dB, $\mu_{\tilde{\chi}} = 2.7$ dB, $\sigma_{\bar{\chi}} = 2.6$ dB, and $\sigma_{\tilde{\chi}} = 1.2$ dB [16]. The noise variance and capacity are evaluated assuming a bandwidth of $B_w = 6$ MHz. The Monte Carlo simulation is performed using $N = 1000$ steps.

Fig. 2 shows the complementary cumulative distribution function (CCDF) of ergodic capacity for simulated areas at

¹GeoTIFF is a raster image file format that contains geospatial metadata, allowing the extraction of geographic information.

TABLE I
COORDINATES OF THE BSS CONSIDERED IN THE SIMULATIONS.

BS Index	Latitude	Longitude	BS Height (m)
1	-15.692700	-47.8541400	105
2	-15.691944	-47.8536111	80
3	-15.699170	-47.8294400	178
4	-15.699167	-47.8297222	178
5	-15.699170	-47.8297200	177.75
6	-15.790556	-47.8933333	170
7	-15.699300	-47.8294194	178
8	-15.692690	-47.8541400	81
9	-15.699170	-47.8297200	178
10	-15.790610	-47.8929400	143.5

a carrier frequency of 195 MHz, under different transmit power levels. The figure presents global CCDF curves as well as separate curves for LoS and NLoS links. Vertical lines indicate the data rates required for 1080p (7.5 Mbits/s) and 4K (37.3 Mbits/s) video transmission, as reported in [3]. At a transmit power of 60 dBm (1 kW), approximately 50% of the evaluated area achieves an ergodic capacity above 7.5 Mbits/s, while only 20% exceeds the 4K rate of 37.3 Mbits/s. Increasing the power to 80 dBm (100 kW) yields more than 95% coverage for the 1080p rate and nearly 70% for the 4K rate. This represents a nearly fourfold improvement in coverage for the higher rate, indicating a nonlinear relationship between transmit power and service availability, especially for demanding applications. LoS conditions yield substantially higher capacities than NLoS. For the 80 dBm scenario, almost the entire covered area with LoS conditions reaches rates exceeding the considered thresholds. In comparison, approximately 65% of NLoS areas exceed 37.3 Mbps in capacity. This highlights that NLoS links are the primary bottleneck for high-rate services: even at high power, about one-third of NLoS regions fail to support 4K streaming.

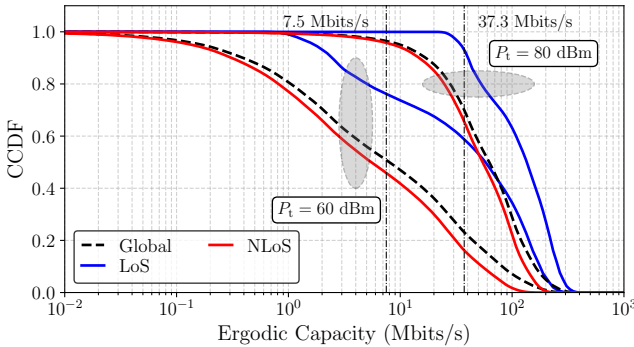


Fig. 2. CCDF of ergodic capacity at 195 MHz for P_t of 60 dBm and 80 dBm, with LoS/NLoS breakdowns. Dashed lines indicate the rates required for 1080p (7.5 Mbits/s) and 4K (37.3 Mbits/s) video transmission.

Fig. 3 presents the average ergodic capacity as a function of transmit power P_t (in dBm) for the five frequency bands considered in the TV 3.0 application. The simulation results show good agreement with a power-law model of the form $\bar{C}_{\text{fit}} = a \left(\frac{P_t}{1 \text{ W}} \right)^b + c$, where the constants a , b , and c are obtained by minimizing the mean squared error. The fitted parameters are listed in Table II, and the resulting curves are overlaid on the simulation data in Fig. 3. As expected, lower

frequencies yield higher average capacities due to reduced path loss. At $P_t = 80$ dBm, the 195 MHz carrier achieves an average capacity of approximately 80 Mbits/s, whereas the 600 MHz carrier reaches only 40 Mbits/s under identical conditions. This factor-of-two reduction highlights the severe impact of frequency-dependent propagation losses, which is particularly relevant for spectrum planning in the ultra-high frequency (UHF) band. The proposed power-law expression enables direct calculation of the transmit power required to achieve a target average capacity. Table II reports the power needed to reach the 1080p threshold (7.5 Mbits/s) and the 4K threshold (37.3 Mbits/s). Higher frequencies demand substantially higher power to meet the same capacity goal. For instance, achieving an average capacity of 37.3 Mbits/s requires only 65.32 dBm at 195 MHz, but 79.00 dBm at 600 MHz, a difference of nearly 14 dB. This underscores the trade-off between spectral availability and power efficiency.

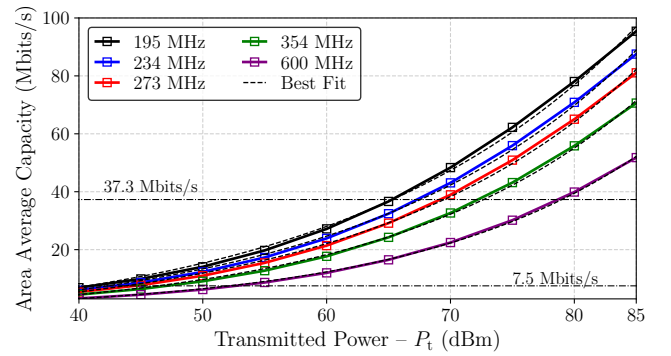


Fig. 3. Average ergodic capacity as a function of transmit power P_t for five frequency bands used in TV 3.0 (195 MHz to 600 MHz).

TABLE II
POWER-LAW FIT COEFFICIENTS AND REQUIRED TRANSMIT POWER TO REACH 7.5 MBITS/S AND 37.3 MBITS/S AVERAGE CAPACITY PER FREQUENCY BAND.

Freq. (MHz)	a	b	c	$\hat{P}_t$ (7.5 Mbits/s)	$\hat{P}_t$ (37.3 Mbits/s)
195	10.39	0.18	-8.84	40.72 dBm	65.32 dBm
234	8.31	0.19	-6.87	42.31 dBm	67.58 dBm
273	6.89	0.20	-5.52	43.75 dBm	69.49 dBm
354	5.05	0.21	-3.78	46.36 dBm	72.67 dBm
600	2.76	0.23	-1.64	52.17 dBm	79.00 dBm

Fig. 4 shows percentile capacity curves as a function of transmit power P_t (in dBm) for the five frequency bands considered in the TV 3.0 system. The indicators P_{50} and P_{95} denote the 50th and 95th percentiles, respectively. At 195 MHz and a transmit power of 80 dBm (100 kW), the median capacity (P_{50}) is above 70 Mbit/s, while the 95th percentile (P_{95}) exceeds 10 Mbit/s. In contrast, at 600 MHz with the same power, the P_{50} and P_{95} values drop to approximately 20 Mbit/s and 1.5 Mbit/s, respectively. This difference highlights the severe impact of frequency-dependent propagation losses on both typical and worst-case coverage. For high-reliability coverage (P_{95}), the 600 MHz band requires power exceeding 80 dBm, a level often impractical under typical broadcast

regulatory limits. Taking into account video quality thresholds, meeting the 4K rate (37.3 Mbit/s) in the 50th percentile requires substantial power. For example, at 234 MHz, achieving $P_{50} \geq 37.3$ Mbit/s requires approximately 75 dBm. At that same power and frequency, the 95th percentile is only 3 Mbit/s, underscoring the large gap between median and edge coverage. These curves provide operators with a practical tool to balance transmit power against target capacity and coverage percentage requirements, enabling informed trade-offs between service quality and deployment cost.

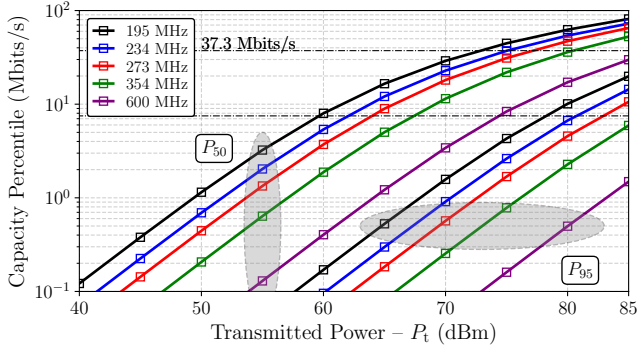


Fig. 4. Percentile capacity curves (P_{50} and P_{95}) as a function of transmit power for five frequency bands (195–600 MHz) in the TV 3.0 system.

IV. CONCLUSIONS

This work analyzed the ergodic capacity of a TV 3.0 link employing dual-polarized 2×2 MIMO transmission under realistic propagation conditions. By combining geographic information, terrain topography, land cover classification, LoS characterization, ITU-R P.1812-based path-loss prediction, and Monte Carlo simulations, the proposed framework enabled a spatial assessment of capacity for different frequency bands and transmit power levels. The numerical results obtained for ten transmission sites in Brasília, Brazil, show that LoS links provide substantially higher capacity than NLoS links, with NLoS regions representing the main limitation for high-rate services. At 195 MHz, increasing the transmit power from 60 dBm to 80 dBm raises the 1080p rate requirement fulfillment from approximately 50% to more than 95%, while the 4K service availability increases from about 20% to nearly 70%. The results also indicate that lower frequency bands provide significantly higher average capacity due to reduced propagation losses, whereas higher frequency bands require larger transmit power to achieve similar performance. This highlights the importance of jointly considering frequency selection, transmit power, LoS/NLoS conditions, and coverage probability in the deployment planning of TV 3.0 systems.

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