Quantitative Assessment of VHF and UHF Bands in Brazil After the Analog TV Switch-off

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***Abstract*— In this paper, we study the usage of 174-216 MHz VHF band and 470-698 MHz UHF band after the analog TV switch-off in Brazil, expected to be finished in December 2023. After a database analysis, we estimated that more than 16 thousand Digital TV channels will be operative. Coverage simulations of these channels were predicted using Recommendation ITU-R P.1812, whose results show that on average 177 MHz in the studied bands will be idle in the Brazilian municipalities. Spectrum usage results indicate the viability of introducing other services rather than broadcasting in the VHF/UHF bands, such as TV White Spaces Devices, but also indicate difficulties for the deployment of Next-Generation Digital TV Systems.**

***Keywords*— Digital Terrestrial Television (DTT), Spectrum Policies, TV White Spaces (TVWS), VHF/UHF Band.**

I. Introduction

Digital terrestrial television (DTT) plays an important role worldwide in providing free-to-air audiovisual content with better picture and sound quality and is being introduced in the VHF/UHF bands by administrations since 1997 [1]. In Brazil, DTT is deployed in the 174-216 MHz VHF Band (channels 7 to 13) and in the 470-698 MHz UHF Band (channels 14 to 51), according to the Brazilian National Agency of Telecommunications (Anatel) technical rules [2].

The analog-to-digital switch-over in Brazil started in 2016 and is expected to be concluded in December 2023 [3], [4]. After the transition, a huge amount of spectrum resources will be released. However, some rules for the usage of idle spectrum in VHF/UHF Bands from TV White Spaces Devices have already been taken and studies for the deployment of Next-Generation Digital TV Systems have already been initiated [5].

This paper analyzes the usage of 174-216 MHz VHF band and 470-698 MHz UHF band after the analog TV switch-off in Brazil to develop possible regulatory actions that could be taken. In Section II, we begin by analyzing the DTT channeling after the analog TV switch-off in Brazil. Next, in Section III, we analyze the spectrum usage with coverage simulations. Lastly, in Section IV, we draw some conclusions.

II. DTT Channeling after the analog TV Switch-off in Brazil

The first phase of the transition from analog to digital terrestrial television broadcasting in Brazil was successfully finished in January 2019. It has included 1,379 municipalities (129.6 million inhabitants, 62.6% of the Brazilian population), including all state capitals, metropolitan areas, and other areas where the analog switch-off was required to clear the 700 MHz band. For the rest of the country (77.3 million inhabitants, 37.4% of the population, distributed in 4,191 municipalities), it is expected that the analog television switch-off will be finished at the end of 2023.

Since the introduction of DTT services in Brazil, in the middle of 2007, 19,721 channels were planned and included in the Brazilian Master Register for Digital Television Channels, a database for broadcasting channels managed by Anatel [6]. However, not all DTT channels are currently in operation. Furthermore, a database of operational DTT stations is currently unavailable. So we have made some assumptions to retrieve data from Anatel's database source.

We consider that all registers containing at least a valid DTT authorization act issued by the Ministry of Communications, and an assigned radio frequency act published by Anatel, configure an operational station. These documents were considered for selecting stations due that without both of them Brazilian broadcasters are not able to start transmissions. The obtained result is that 12,711 DTT channels (about 64.45% of the total number of planned channels) are estimated to be operational in Brazil. Applying the same methodology, it is estimated that 9,230 analog TV stations are still operative. Figure 1 shows the distribution of the estimated operative TV Channels in Brazil.

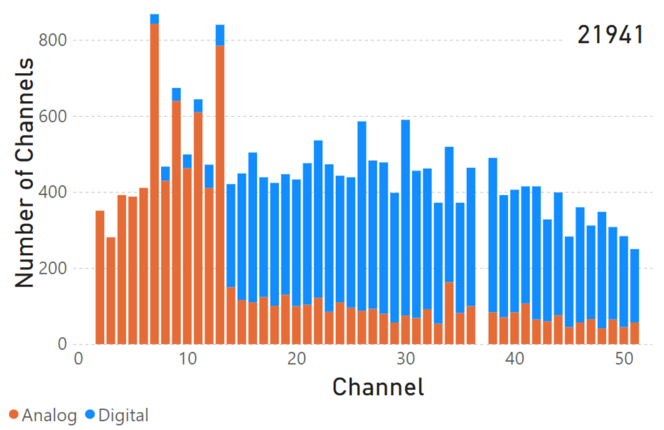

Fig. 1. Distribution of Operative TV Channels in Brazil.

It is estimated that all 9,230 channels will no longer be operative after 2023. So, direct impact of the analog switch-off is that spectrum usage of the VHF Band will suddenly

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decrease, considering that about 65% of analog TV channels are operating in this band. The impact o UHF Band usage will also be relevant – 3,225 analog channels in this band will also cease operations.

On the other hand, there is a huge amount of planned DTT channels (7,010) that are currently not operative. Part of these channels are reserved for the completion of the digital transition and will soon begin operations. Furthermore, in 2021 the Brazilian Ministry of Communications established a government program to facilitate the transition for DTT [7]. The main objective of the program is to install complete shared DTT transmission sites in 1,638 small municipalities where only analog TV stations are operative. Besides transitioning current analog TV channels, the program also provides rules for expanding the variety of TV content for the population by adding two new DTT channels (up to 8 different TV programs) on each transmission site for public broadcasters. Funding for the program is provided by resources from the 700 MHz band auctioning process for 4th Generation IMT Systems, which account for approximately US$ 170 million, specifically reserved as counterparts for the digital dividend [8].

From the total amount of not operative channels, it is estimated that 3,781 will have a high probability to start operating in the short-term, as public policies for funding transmission sites are already established. The remaining not operative channels are reserved for long-term spectrum policies. So, besides 9,230 analog channels will soon cease operations with the analog switch-off in Brazil, new DTT channels are expected to start transmissions in the short-term. Hence, DTT channel distribution in Brazil after the analog switch-off is expected to contain about 16,492 operative channels as illustrated in Figure 2.

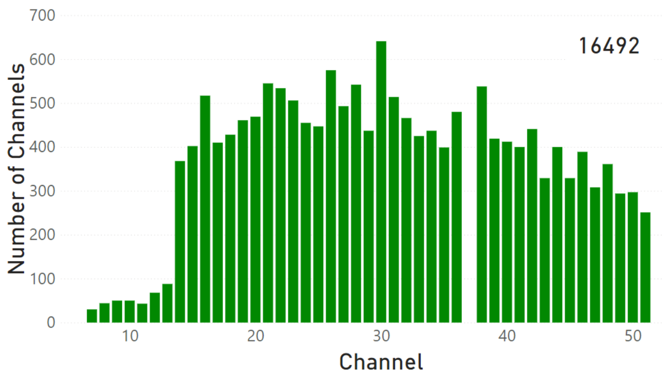

Fig. 2. Expected distribution of Digital TV Channels in Brazil after the analog switch-off.

III. Spectrum usage analysis

In Section II we showed the expected DTT channeling after the TV analog switch-off in Brazil. To evaluate spectrum usage of TV Services in the Brazilian territory, simulations were made to estimate the coverage of all operating channels. The applied methodology is described in the following subsections. The web-based spectrum management software, Spectrum-E, has been provided through the courtesy of Anatel for the simulations.

A. Database Analysis

As few of the total DTT Channels are currently licensed, the availability of technical data containing the necessary inputs for simulating the estimated coverage is scarce. It occurs because only by completing the registration of the station's parameters (antenna height, radiated diagram, ERP, etc) technical data can be retrieved from Anatel's database. So, once again, some assumptions were considered. For simulating all predicted coverage, an algorithm from Spectrum-E software that simulates an ideal station was applied. This algorithm calculates the best antenna diagram and ERP for a station in a determined location. It takes the maximum protected contour, determined by Anatel Technical Regulation [9], and terrain data to perform calculations. The result is that for each channel it is created an ideal station that could reach the maximum protected contour in each direction, from 0 to 360 degrees with a 1-degree step. Figure 3 shows an example of a computed antenna pattern in a rough terrain profile. The protected contours are plotted in those figures using Recommendation ITU-R P.1546-5 [10], which is the reference prediction method for determining the maximum protected area of a DTT station, as defined by Anatel [9].

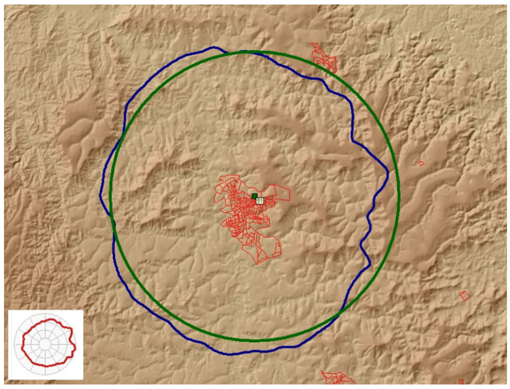

Fig. 3. Example of a computed antenna pattern in rough terrain.

B. Simulation Parameters

The estimation of the coverage of DTT stations involves frequency management aspects and databases with equipment-related information; accurate knowledge of terrain data where the system is to be deployed; and detailed information on the distribution of the population inside the service area. In addition, the nature of the propagation model in use will be of paramount importance for realistic predictions and efficient and precise network dimensioning [11].

For the purpose of the present paper, the Recommendation ITU-R P.1812-5 was chosen to estimate the coverage of all 16,642 operating DTT channels. This ITU-R Recommendation provides a deeper consideration of potential propagation phenomena and it will provide more accurate path loss results in some specific links. In consequence, ITU-R states that P.1812

TABLE I
ITU-R P.1812 SIMULATION PARAMETERS

Parameter	Value
Receiving Height	10 m
Calculated Distance	100 km
Percentage of time	50 %
Percentage of locations	50 %
Subpath	Delta Bullington
Clutter Resolution	Default
Terminal Clutter Losses	Not considered
Profile Sampling	1,000 points

should be used for the detailed evaluation of point-to-area signal levels [11], [12].

Furthermore, ITU-R P.1812 is a modern recommendation (last updated in August 2019) and the ease of reproducibility of results and implementation transparency of the ITU-R P.1812 model can allow for a better degree of standardization of a propagation prediction method for point-to-area terrestrial services in the VHF and UHF frequency bands [13]. Parameters of Table I were used to achieve a balance between speed and accuracy of the simulations.

Finally, to determine the service area it was considered the minimum field strength defined by Anatel on its technical rules: 51 $dB\mu V/m$ for channels in the UHF band and 43 $dB\mu V/m$ for channels in the VHF band (see Table 1 in [9]).

C. Results

After establishing all the required parameters, simulations were made to predict the service area of all considered DTT stations. Figure 4 illustrates the predicted coverage of channel 20.

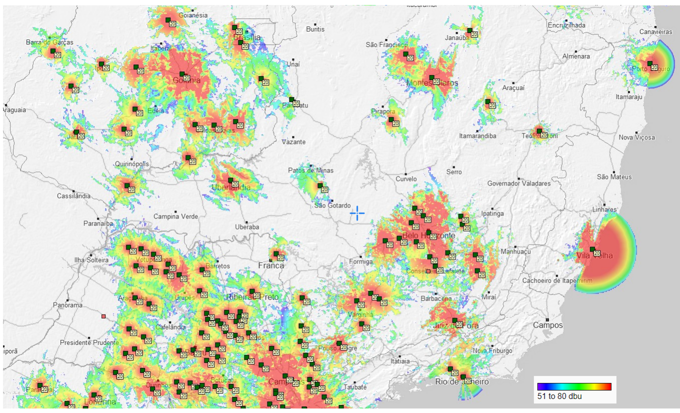

Fig. 4. Example of predicted coverage for DTT Channel 20.

The population distribution inside the service area was calculated considering the percentage of coverage on each sector of the census geographic boundary shapefiles provided by the Brazilian Institute of Geography and Statistics [1]. A municipality was considered covered by a DTT station when at least 90% of its urban population is inside the predicted coverage area. Results are shown in Figure 5, which contains the number of municipalities covered by each DTT Channel. The numerical results of the simulations are summarized in Table II.

[1]Based in 2010 census, available at https://www.ibge.gov.br/geociencias/organizacao-do-territorio/malhas-territoriais/26565-malhas-de-setores-censitarios-divisoes-intramunicipais.html?=&t=downloads

TABLE II
NUMBER OF MUNICIPALITIES WITH AT LEAST ONE DIGITAL CHANNEL PER FREQUENCY BAND.

Frequency Band	Municipalities with at least one digital channel (percentage)
All Bands	5398 (96.91%)
174 - 216 MHZ (Channels 7 - 13)	1502 (26.97%)
470 - 608 MHz (Channels 14 - 36)	5334 (95.76%)
614 - 698 MHz (Channels 38 - 51)	4724 (84.81%)

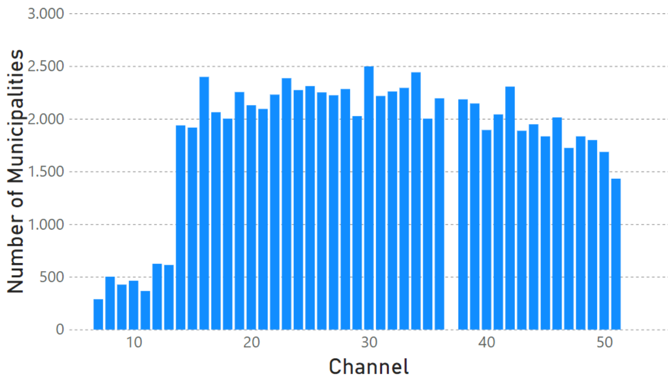

Fig. 5. Number of municipalities covered by at least one DTT Channel.

A straightforward finding that can be extracted from data analysis is that digital television will reach nearly 97% of the Brazilian municipalities. Digital reception, as expected, is concentrated in the UHF Band - only 27% of Brazilian municipalities will be able to receive DTT service in channels 7 to 13. On the other hand, considering the number of received channels per municipality, about 50% of the municipalities that receive at least one DTT channel will have no more than 13 DTT channels (78 MHz) as shown in Figure 6. It indicates that besides DTT penetration is undoubtedly remarkable, there are idle spectrum bands in both VHF and UHF bands in Brazil.

To evaluate the expected spectrum availability average (S), the methodology of Equation 1 was considered.

$$S = \frac{\sum_{i=1}^{N}(A - R_i).B}{N} \quad (1)$$

where:

A = total number of allocated channels for DTT services
R_i = number of received channels in the ith municipality
B = DTT channel bandwidth (MHz)
N = number of municipalities

The spectrum availability average of all Brazilian municipalities after the analog TV switch-off was computed using $N = 5,570$, $B = 6$ and $A = 44$. The value of A reflects the total number of 6 MHz channels available in the 174-216 MHz

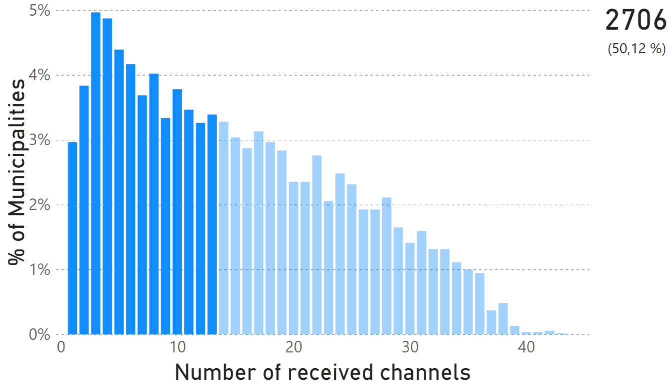

Fig. 6. Percentage of municipalities covered per number of channels in each municipality in Brazil.

VHF band and 470-698 MHz UHF band together. The result shows that on average 177 MHz will be idle in Brazil after the analog switch-off. In most of the cities (73%) the 174-216 MHz VHF band (42 MHz) will be totally released. Results are geographically illustrated in Figure 7 - greener areas have more spectrum availability.

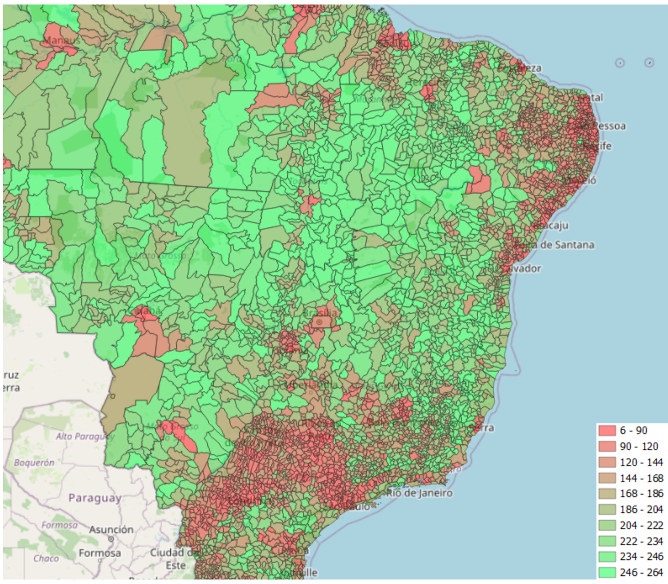

Fig. 7. Estimated spectrum availability per municipality (in MHz).

D. Future Spectrum Usage

Discussions about the usage of idle spectrum in VHF and UHF Bands have already been initiated in Brazil. In October 2021, Anatel issued a resolution to define criteria for the usage of TV White Spaces (TVWS) [14]. This resolution defines frequency band blocks for the deployment of White Spaces Devices and also the methodology to guarantee the protection of television services. The maximum peak power of the White Space Devices, measured at the transmitter output, cannot exceed 1 $Watt$. However, further technical detailing is still under discussion.

As the transmission power of white space devices will be low compared to the high-power high-tower broadcasting transmission schema, it is not expected interference issues in DTT services. Furthermore, in all Brazilian municipalities, there is at least one 6 MHz for the deployment of TVWS. However, the feasibility of introducing TVWS Devices will require spectrum management tools to identify the spectrum availability by using geo-referenced databases or sensing methods, as already required by national regulations.

For the deployment of mobile services, however, coexistence with DTT services in the same allocated band is quite complex, being an object of discussions at the international level, mainly within ITU, that has issued a specific report about the subject [15]. That is why in most cases, having spectrum in the UHF identified for IMT indicates that the broadcasting service should be re-farmed from the band and moved to another one [16]. So, to deploy IMT services in 600 MHz (614-698 MHz), for instance, a refarming process has to be evaluated for the 5,168 channels that are estimated to be operative in the band. The spectrum availability assessment shows that is technically impracticable to release the entire 600 MHz Band, as in many areas (pinker areas of Figure 7) the number of available channels is lesser than the number of channels allocated in the band.

The evolution of DTT Services is also under discussion worldwide, and its results will impact the usage of VHF and UHF Bands. The second generation of digital terrestrial television broadcasting transmission systems is meant as systems offering higher bit rate capacity per Hz and better power efficiency in comparison to the systems described in Recommendation ITU-R BT.1306 and there is no general requirement for backward compatibility with first-generation systems [17]. So, transitioning from first to second-generation DTT systems will require spectrum availability.

In Brazil, studies for Next-Generation Digital TV Systems have already been initiated. In July 2020, The Brazilian Digital Terrestrial Television System Forum (SBTVD Forum) released a Call for Proposals (CfP) seeking inputs from interested organizations for Brazil's next-generation Digital Television system components and sub-components [5]. The initiative is called "TV 3.0 Project". For any chosen technology for the system's physical layer, the transition from first to second-generation DTT systems will require a simulcast period. However, unlike the regulatory actions taken for the analog-to-digital switchover, the spectrum availability results presented in this paper, indicate that it will not be possible to designate a 6 MHz channel for each broadcaster.

IV. Conclusions

This paper presents important contributions to the discussions of efficient spectrum usage of the 174-216 MHz VHF band and 470-698 MHz UHF band in Brazil. It presents coverage simulations results using Recommendation ITU-R P. 1812 that quantifies the spectrum availability in the referred bands for each Brazilian municipality, indicating that on average 177 MHz will be available after the analog TV switch-off. Simulations were made considering also the expected deployment of new DTT channels, based on the assessment of Anatel's database and public policies that have been established by the Ministry of Communications.

Numerical results pointed out that the spectrum availability in the studied bands will enable the introduction of TVWS devices in all Brazilian municipalities, due to its limited maximum peak power. Nonetheless, the introduction of mobile services in 600 MHz (614-698 MHz) will require a huge refarming process and it is impracticable to be applied in all Brazilian regions. Furthermore, evolution for second-generation DTT systems will require spectrum availability, considering that no general requirement for backward compatibility with first-generation systems has been established for the introduction of new DTT systems.

As future works, we envisage simulating the estimated denied spectrum generated by DTT channels considering co-channel and adjacent channel interference to optimize DTT frequency planning and better identify areas where spectrum can be used for facilitating the introduction of TVWS and second-generation DTT systems.

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