TV White Space Availability in Libya

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Abstract. TV White Space (TVWS) has gained much attention recently as a potential new frontier for spectrum-hungry wireless applications. The impact of TVWS technology depends on the availability and status of TVWS spectrum. Multiple studies have been conducted to assess the availability of TVWS spectrum in many countries and regions. In this paper, we present the results obtained on assessing the availability of TVWS spectrum in Libya. Radio propagation analysis was conducted to predicted coverage of TV stations and a threshold-based method based on the minimum field strength was adopted to determine TVWS availability. A minimum of 58% of channels in the UHF TV spectrum were found to be available on average in the most populated region of the country. These results promise great potentials for TVWS technology in Libya.

Keywords: TV White Space · Spectrum management · Spectrum sharing

1 Introduction

The communication spectrum is a scarce national resource of which effective management and regulation is crucial for the development of any nation's economy. Sound long-term spectrum planning and management policies are key to maximize the benefits to the national economy and ensures healthy growth of the ICT sector and infrastructure. In this context, TVWS represents a new challenge to spectrum management while at the same time promising to enable an array of new technologies and applications to support better utilization of the communication spectrum and achieve positive economic return on the national scale.

1.1 What is TVWS?

TV White Space refers to the underutilized frequency bands in the VHF and UHF frequency rage that are traditionally allocated to terrestrial TV broadcast services. The size and the state of these bands vary widely from country to country and from region to region. In most regions of the world much of the white space is in the range of 47–790MHz. The term white space originally referred to the guard bands deliberately left blank between analogue TV channels to avoid

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interference. Applications utilizing these bands (called secondary users) must not interferer with the existing TV broadcasts and other applications licensed in the area (primary users).

1.2 Why TVWS?

Harvesting unused TVWS is of great importance because of the superior properties of the VHF and UHF bands. Devices transmitting in the VHF and UHF range require lower power and the signal can travel longer ranges compared to the higher frequencies such as the 2.5 GHz used for WiMax for instance. Current standards implementing TVWS and Cognitive Radio such as the IEEE802.22 WRAN promise to provide coverage from a single base station for up to 30-100km [11]. In addition, VHF and UHF frequencies have superior propagation properties both indoor and outdoor where no line-of-sight is required for good reception. These characteristics make TVWS technologies a good candidate to provide wireless information services to rural areas with minimum infrastructure investments.

1.3 TVWS in Libya

Libyan regulators are yet to adopt regulations governing the use and deployment of TVWS technology and devices in the country. Radio regulation in Libya is closely aligned with the ITU global and regional policies and regulations. Libya is in ITU-R Region-1 encompassing Europe, Africa, and much of Asia. Therefore, any future TVWS regulations and policies will be closely similar to that of ITU-R Region-1 countries. In 2013, the Libyan Ministry of Communications and Informatics (MCI) released the Libyan National Frequency Plan (LNFP) for public consultations and comments on future directions for national spectrum planning including the topics of spectrum sharing, cognitive radio, and TVWS [4]. According to the LNFP, the spectrum allocations in the VHF range from 47MHz to 230MHZ and the UHF range from 470MHz to 790MHz assigned for broadcasting services are shown in figure 1.

It can be seen from this figure that TV broadcast bands are more abundant in the UHF range than VHF range. Moreover, the bands in the VHF are more fragmented which adds more complexity to spectrum management and decreases the potential benefits of these bands. This analysis is consistent with ITU-R region 1 countries including the EU countries where more focus is given to the UHF bands as the primary bands for TVWS. As such, any future implementation of TVWS systems in Libya will be similar to that in Europe and will most likely focus on exploiting white space in the UHF bands. However, the large geographical area of Libya and the low population density may allow for VHF bands utilization in TVWS thus increasing the potentials of TVWS technology in providing wireless access to rural areas throughout the country and help in closing the digital divide. Extensive studies are needed to assess the actual availability of TVWS bands and the potentials of TVWS technologies. This work is a contribution in this direction.

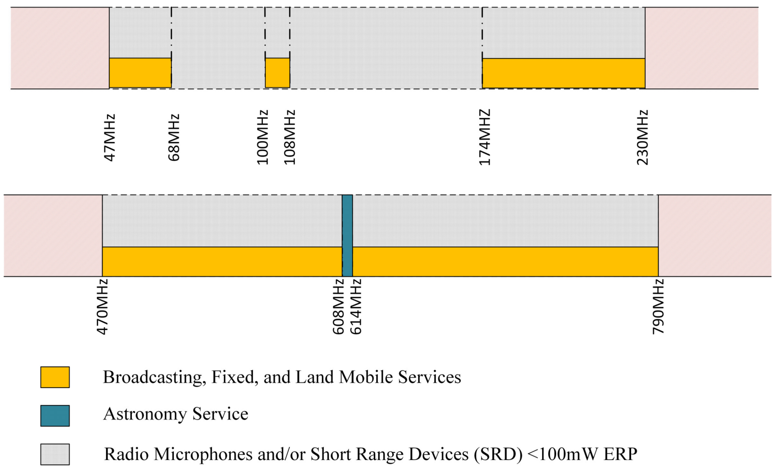

Fig. 1. LNFP in the 47-230MHz VHD and the 470-790MHz UHF ranges

2 Related Work

TVWS estimation studies have been conducted in various parts of the world. In [3] the authors study the availability of TVWS in 11 European countries using the ITU-R P.1456 and the Longley-Rice (ITM) models. They concluded that almost 56% of the 470MHz-790MHz UHF bands are available with only co-channel protection. This number drops to 25% if adjacent channel restrictions are applied. The study only considered transmissions from TV stations. In [2] the authors present their results for TVWS availability in Italy and conclude that TVWS in Italy is available mostly in areas with light population density. A threshold-based approach is used in this study. Further studies are conducted for TVWS availability in India [9], Australia [5], and Japan [10]. All of these studies confirm the potential of TVWS technology in providing additional spectrum for existing and new applications but with varying degrees in each country.

To the author's best of knowledge, there has been no previous attempt to estimate the availability of TVWS in Libya. This work aims to close this gap by estimating TVWS availability in various test regions in Libya using a threshold-based approach.

3 TVWS Estimation

Estimating the availability of TVWS depends heavily in regulatory-set parameters and rules that define the protection regions for TV transmitters and received power threshold for acceptable TV reception for example. Different methods are adopted by different regulators. For this study, we adopt a threshold-based model and design an algorithm to estimate the availability of TVWS.

3.1 TVWS Estimation Algorithm

In order to compute the availability of TVWS the designated area is first divided into a grid of k x k pixels as in figure 2. At each pixel, a virtual receiver is assumed with antenna height h_{rx}. For each receiver, a propagation model is used to predict the received signal strength from every possible transmitter on all frequency channels. If the predicted Field Strength from all possible receivers is below a specific threshold, the pixel is designated as white space for the current frequency channel. Algorithm 1 explains these steps.

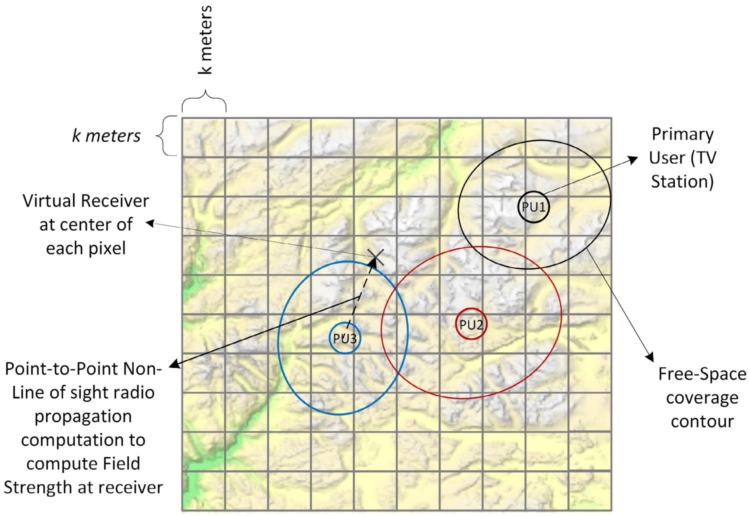

Fig. 2. TVWS Estimation

3.2 Point-to-Point Radio Propagation Computation

The Irregular Terrain Model (also called the Longley Rice model) [8] and The ITU-P.1546 [6] propagation models where both used to predict the received Field Strength (dBuV/m) at each receiver in the test area from each possible transmitter. The ITM model is a radio propagation module for frequencies from 20MHz-20GHz developed by A.G. Longley and P. L. Rice in the 1960s. The module incorporates statistical signal analysis with terrain information to predict median field strength (dBuV/m). An-open source tool called SPALT [7] was used to perform the path loss computation based on the Irregular Terrain Model (ITM).

The second model used is the ITU-P.1546 Propagation Model. This model is published by the International Telecommunications Union (ITU) and is recommended for use for terrestrial TV broadcast coverage prediction for frequencies

Algorithm 1. TVWS Estimation Algorithm

```
Data: Receivers, Transmitters, Frequencies, DTM maps
Result: TVWS Availability
initialization;
for All Frequencies do
    for all Receivers do
        for all Transmitters do
            Calculate received power at current receiver location;
            if Field Strength >= Threshold then
                Not white space;
                Go to next receiver;
            end
            Designate pixel as white space;
        end
    end
end
```

in the range of 30MHz-3GHz. The model is based on a set of field-strength curves for different frequencies, antenna height, and distances with equations for interpolation and extrapolation for a range of these values. A MATLAB program was used for the ITU model calculation.

3.3 Field Strength Threshold

The Field Strength at the receiver is compared to a thresholds based on the minimum acceptable location probability. Location probability in TV broadcast planning represents the probability of successful signal reception in a small area (usually 100m by 100m). This probability is critical in determining the coverage area of each transmitter and thus defines the area of service. Table 1 shows different location probabilities for different service types with corresponding minimum field strength values of the received signal based on 2006 ITU Geneva agreement (GE06)[1].

Table 1. Location probabilities and field strengths for different service types

Location Probability	Minimum Field Strength	Service Type
99%	60 dBuV/m	Mobile TV
95%	56 dBuV/m	Fixed Digital TV
50%	48 dBuV/m	Fixed Analogue TV

4 Results

TVWS availability in Libya was estimated using TV transmitters' data obtained from the ITU databases and the regulator in Libya. The data included 343 TV

Fig. 3. Test Area 1 (5 TV stations)

stations in the UHF range from 470MHz to 790MHz providing TV coverage for the towns and cities of Libya. The assessment was conducted on two test areas:

1. Test Area 1
   A smaller area encompassing the capital city of Tripoli and the western mountains of "Jabal Nafosa". This area is of the most populated in the country and features interesting mix of terrain from coastal urban environment to mountainous rural terrain. The area contains five sites for primary analogue TV stations each consisting of multiple transmitters in the UHF range (470MHz-79MHz). Figure 3 shows a map of this area.

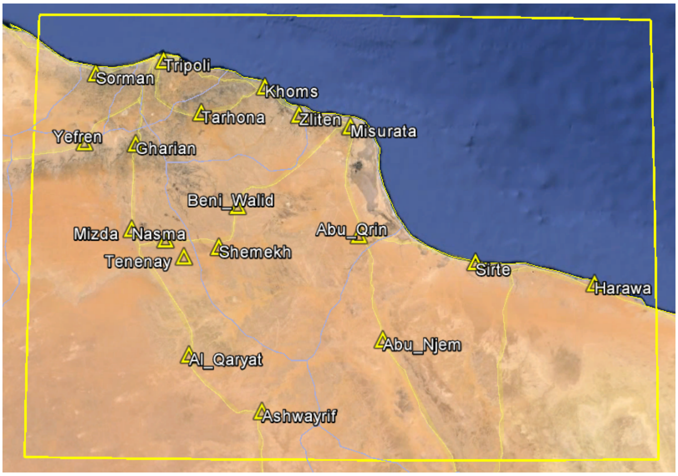

Fig. 4. Test Area 2 (19 TV stations)

2. Test Area 2
   A larger area covering the entire western coastal area of Libya. This area covers multiple large cities (Tripoli, Misurata, Azzawia, ...) were existing TV coverage may limit the availability of TVWS but also includes rural areas and smaller towns were TVWS may be abundant. Figure 4 shows a map of this area.

The test areas were divided into a grid of pixels of 1000m by 1000m each. A receiver is assumed at each pixel and the received signal strength in term of Field Strength (dBuV/m) was measured from each transmitter in the area. If the maximum signal strength is below a certain threshold, the pixel is deemed as white space. The process is repeated for each frequency. The Irregular Terrain Model (ITM) and the ITU-P.1546 propagation models were used to predict the received field strength at each location in the test area. Below are the results obtained using each of the two models.

4.1 Irregular Terrain Model Results

Table 2 shows the percentage of total available channels in the UHF range of 470MHz to 790MHz in test area 1 at different threshold level. Each threshold level corresponds to the minimum field strength for different primary service below which reception of the service becomes unacceptable. For instance, field

Table 2. TVWS availability results with Longley-Rice (ITM) propagation model

Primary service type	Threshold (dBuV/m)	TVWS availability (%)	Average spectrum available (MHz)
Fixed Analog TV	48	58.37	163.27
Fixed Digital TV	56	62.89	176.28
Mobile TV	60	65.05	183.17

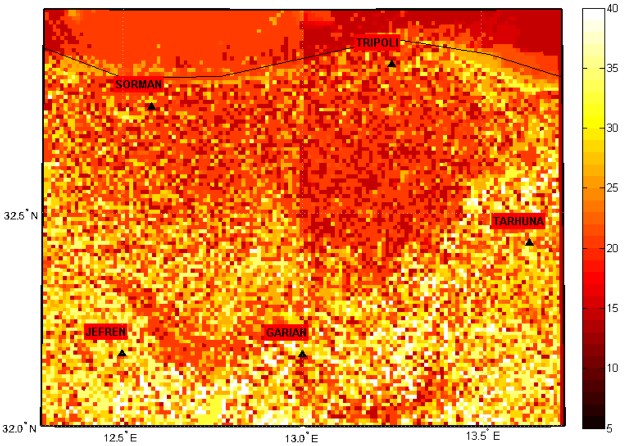

Fig. 5. TVWS heatmap of Tripoli area using Longley-Rice (ITM) model

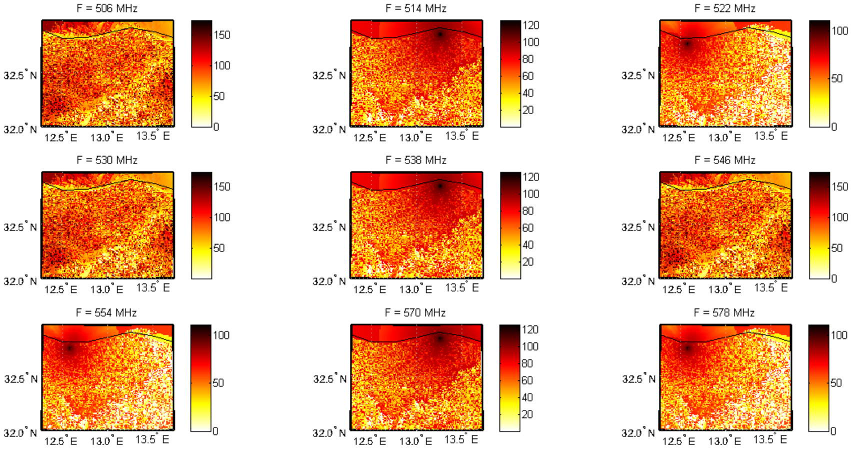

Fig. 6. Heatmaps of field strength values for different channels (ITM model)

Table 3. TVWS availability results with ITU-P.1546 propagation model

Primary service type	Threshold (dBuV/m)	TVWS availability (%)	Average spectrum available (MHz)
Fixed Analog TV	48	60.63	194.02
Fixed Digital TV	56	69.49	222.35
Mobile TV	60	74.22	237.50

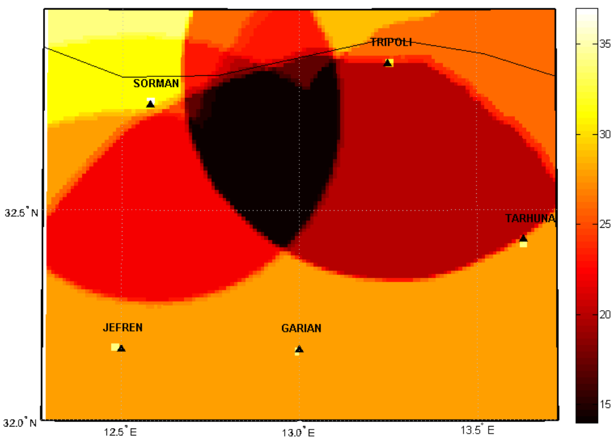

Fig. 7. TVWS Availability in Tripoli area using ITU-P.1546 propagation model

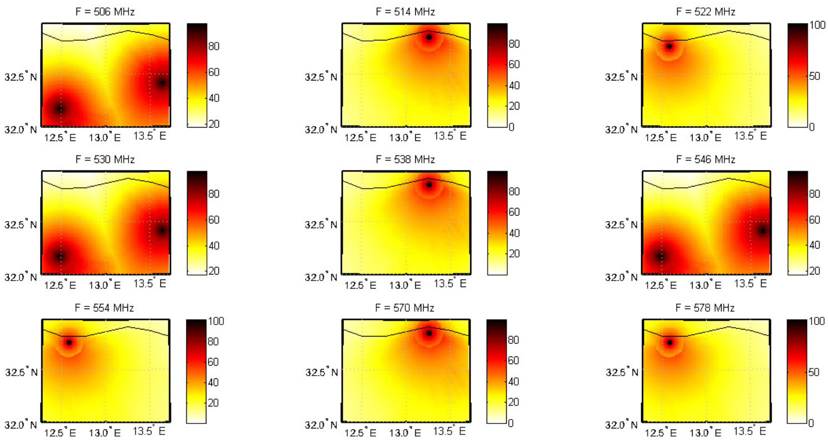

Fig. 8. Heatmaps of field strength values for different channels (ITU-P.1546 model)

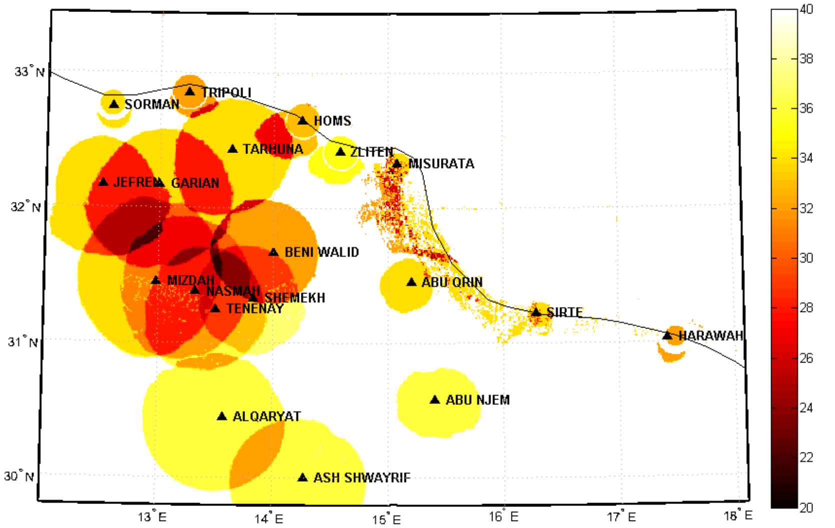

Fig. 9. TVWS availability in the western coastal area of Libya (ITU-P.1546 model used)

strength at a receiver for analog TV below 48 dBuV/m renders the service unacceptable. As the threshold level increases (when going from fixed to mobile service for instance), the percentage of available TV channels for secondary use will also increase. This is a direct result of the fact that increasing the threshold level corresponds to decreasing the protection margin of the primary service, thus resulting in more channels being available for secondary use.

Figure 5 shows a heatmap of test area 1 with the total available channels at each pixel represented by a color from the range shown.

Figure 6 shows different heatmaps for the field strength values at different channels. The locations of individual TV stations sometimes are apparent in these maps.

4.2 ITU-P.1546 Model Results

The ITU-P.1546 propagation model was also used to predict the signal trength and TV coverage at each pixel in the test areas. Table 3 shows the percentage of total available channels in the UHF range of 470MHz to 790MHz in test area 1 at different threshold level. As in table 2, Each threshold level corresponds to the minimum field strength for different primary service below which reception of the service becomes unacceptable.

We notice that the percentages of total available TVWS channels using the ITU-P.1546 model are higher than those obtained with the ITM model. This can be attributed to the statistical nature of the ITU model and the fact that the ITM model captures the effect of the terrain more that the ITU model. Figure 7 illustrates the availability of TVWS channels in test area 1 as predicted using the ITU-P.1546 model.

The second test area on which the assessment was conducted included the entire western coastal region of the country. Due to computational complexity of the ITM model, only the ITU-P.1546 model was used to assess the TVWS availability in this area. Figure 9 illustrates the results from the assessment with the pixels color coded to correspond to the total available channels at each location.

5 Conclusion

TVWS availability in Libya was investigated through radio propagation analysis using TV broadcast stations' data and elevation models of the country. The Longley-Rice (ITM) and the ITU-P.1546 propagation models were used to assess the received signal strength from each transmitter at every possible location in the designated test areas in the country. Locations were the signal strength fell below the minimum threshold for correct reception were deemed as White Space and were designated for use by secondary applications. For all the tests performed in the most populated areas of the country no less than an average 58.37% of total channels were available over all locations with minimum average available spectrum of 163.27MHz. These results are highly encouraging for future implementations of TVWS technology in Libya. While these results do not consider neighboring channels protection and protection of other primary services in the TV spectrum such as wireless microphones, it is worth mentioning that the TV transmitters data used are highly conservative and include all stations registered by the Libyan regulator with the ITU notification database according to the GE06 agreement. This data does not include operational status information for these stations, and since Libya is going through the transmission from analog to digital TV, most of these analog stations are off-line. in addition, satellite TV remains the most popular TV service in the country and a small portion of the population (if any) rely on terrestrial TV services. All of these factors combined with the obtained results in this study assert the potential of future TVWS applications in Libya.

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