Exploiting The Digital Dividend In TV Spectrum For Cognitive Radio Networks

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***Abstract*— Radio spectrum is a necessary barrier for flourishing of economic activities through provision of wireless services. The radio spectrum suitable for the propagation of wireless signals is a limited resource and hence requires optimal allocation as collectively dictated by regulatory, technical and market domains. The current global move to switch from analogue to digital TV has opened up an opportunity for the reallocation of this valuable resource. In one way, spectrum bands once used for analogue TV broadcasting will be completely cleared, leaving a space for deploying new licensed wireless services, and in another way, digital television technology geographically interleaves spectrum bands to avoid interference between neighboring stations-leaving a space for deploying new unlicensed wireless services. The focus of the paper is to find the availability of geographically interleaved spectrum, also known as television spectrum white spaces (TVWS) and proposing the wireless network scenarios for rural broadband connectivity.**

Keywords—TVWS; NFON; broadband; quantifying;

I. INTRODUCTION

The Government of India is taking many initiatives to provide broadband services by connecting the Gram-Panchayats (local civic bodies in villages) in the rural areas by optical fiber network. The Union Cabinet approved the plan for providing far reaching broadband network called National Optical Fibre Network (NOFN) in October 2011[1]. The plan aims to connect all the Gram-Panchayats in the country with highspeed optical fibre lines. The scheme to bring broadband connectivity to rural areas is estimated to cost Rs. 20,000 crores (app $4 Billion), covering approximately 250000 villages having Gram-Panchayats (i.e. approximately saying villages above the population 1000). The speeds supported by this network envisioned to be nearly 100 Mbps [1]. This task seems to be herculean in terms of time required to make the network operational and huge funds required. Hence this solution seems to be costlier. However even then 400,000 thousands habitations still remain uncovered.

For deeper penetration of broad band services up to 400,000 habitations [2] (population less than 1000) in total and saving on the money and time of exchequer, the smaller villages around the panchayats can be serviced by wireless broadband network. This network is envisioned to operate on TV white spaces. On the other hand, the fiber-optic cable can be laid up to the sub-blocks (5 to 8 per block/taluka) and the area under the sub- blocks can be serviced by the wireless network. In Indian rural areas the broad band services needs to be cheaper and affordable to the general public.

In [3], terrain morphology is used to model channel propagation used in white space calculations. A method in which actual coverage map is considered for quantification of TVWS is discussed in [4]. The TVWS network scenarios are discussed in [5].

Looking at all the aspects of providing affordable broad band services to the rural masses, the solution in terms of wireless services is proposed. The allocation scenario of TV spectrum and available average bandwidth is discussed. The economic value of the network scenario can be evaluated only after quantification white spaces. The analytical formulation for quantifying the TV white spaces is proposed. The distribution of aggregate interference is computed by simulations for analyzing impact on availability of white spaces. Finally, the possible network scenarios and possible per capita capacity that can be provided are discussed.

Section-II presents Analog to Digital Switchover-India Scenario, Section-III presents Scenario classification model for usage of whitespace. Section-IV Implenmentation details of the project with various coverage plots and measurements taken into different regions of Maharashtra. Section-V presents the simulation results and paper is concluded in section-VI .

II ANALOG TO DIGITAL SWITCHOVER-- INDIA SCENARIO

The spectrum available for Terrestrial TV broadcasting along with TV channel distribution in India is given in table 1. Doordarshan, public TV broadcaster of India, has assigned only one channel (channel number 4) out of three channels available in the VHF band for terrestrial TV broadcast. This band is underutilized and completely vacant in future due to switchover from analogue to digital TV transmission which is digital dividend from VHF I band. Doordarshan has assigned all 8 channel of VHF III band for analogue TV transmission. The 470-960 MHz UHF band is allocated for terrestrial broadcasting and mobile services on primary basis in India. Presently, the 470-806 MHz band is available for terrestrial TV broadcasting and 806-960 MHz band is used by fixed and mobile services for transmission of data/voice and video. There are 14 TV channels

ISSN: 2278 – 7798

available in the UHF band-IV (470-582 MHz) with each having channel bandwidth 8 MHz.

Doordarshan has assigned and operating about 330 transmitters in this band. Doordarshan's three digital TV transmitters at Kolkata, Chennai and Mumbai are also operating on an experimental basis in this band. Doordarshan has started its mobile TV service in Delhi using DVB-H technology in this band at channel 26 in May 2007.There are 28 channels available with 8 MHz bandwidth in UHF band-V from 582-806 MHz. Doordarshan has not been assigned any channel in this sub-band for analogue TV transmission. However, frequency 735-755 MHz and 775-795 MHz has been assigned to Doordarshan to operate short distance UHF links. Some of the Government agencies are operating point to point microwave links in 610-806 MHz.

TABLE-1 TV CHANNEL ALLOCATION IN VHF AND UHF BAND [6]

Band available	Spectrum	No of TV channels Available	TV Channel No.
VHF band I	47-68 MHz	3	2-4
VHF band II	174-230 MHz	8	5-12
UHF band V	470-582 MHz	14	21-34
UHF band V	582-806 MHz	28	35-62

TV WHITESPACES: INDIAN SCENARIO

A white space can be defined as the amount of spectrum band on which no significant RF energy is detected at some point in time and space. If the given spectrum band is a legacy spectrum and if there exists a white space at some point in time and space, it can be considered for use by unlicensed wireless services.

VHFIII AND UHF BAND PLAN

TABLE 2: CURRENT SPECTRUM ALLOCATION PLAN IN INDIA

5	6	7	8	9	10	11	12	13	14
174 -- 181	181 -- 188	188 -- 195	195 -- 202	202 -- 209	209 -- 216	216 -- 223	223 -- 230		
15	16	17	18	19	20	21	22	23	24
						470 -- 478	478 -- 486	486 -- 494	494 -- 502
25	26	27	28	29	30	31	32	33	34
502 -- 510	510 -- 518	518 -- 526	526 -- 534	534 -- 542	542 -- 550	550 -- 558	558 -- 566	566 -- 574	574 -- 582
35	36	37	38	39	40	41	42	43	44
582 -- 590	590 -- 598	598 -- 606	606 -- 614	614 -- 622	622 -- 630	630 -- 638	638 -- 646	646 -- 654	654 -- 662
45	46	47	48	49	50	51	52	53	54
662 -- 670	670 -- 678	678 -- 686	686 -- 694	694 -- 702	702 -- 710	710 -- 718	718 -- 726	726 -- 734	734 -- 742
55	56	57	58	59	60	61	62		
742 -- 750	750 -- 758	758 -- 766	766 -- 774	774 -- 782	782 -- 790	790 -- 798	798 -- 806		

VHF band III

Analog TV transmission

585-698 Digital broadcasting services

Cleared spectrum for mobile broadband (4G) 698-806

It has been discussed in the above paragraphs that due to analog to digital transition of TV broadcast in India, considerable amount of spectrum will be free. Some part of this spectrum coming from digital dividend is already planned to be allocated for IMT-Advanced services and remaining part is planned to be allocated for Digital Terrestrial TV Transmission (DTTV).

The proposed DTTV spectrum can be utilized as interleaved spectrum for unlicensed wireless services. The DTTV spectrum is geographically allocated so that DTTV spatial white spaces are available for interleaved transmission of unlicensed wireless services. In Table2, it is evident that, in analog regime, there are 22 channels which can be utilized for interleaved DTTV transmission. Due to transition from analog to digital, 6-8 digital channels can be accommodated in one analog channel, thus obtaining 132-176 digital channels. These channels will be available in frequency range 174-230 MHz and 470-582MHz.This spectrum can be used opportunistically by employing channel allocation database and spectrum sensing.

III. SCENARIO CLASSIFICATION MODEL FOR USAGE OF WHITE SPACES

We follow the scenario classification framework proposed by QUASAR Project [7] to assess the feasibility of use cases proposed. The QUASAR framework introduces four hierarchical levels for classification of scenarios which use TV white spaces.

1. **Secondary Usage Type:**
   The usage type is specified in terms of deployment mode, the level of dependency on secondary spectrum and the data rate requirements imposed by the services intended to be offered by the secondary system.
   Here, deployment mode defines the intended coverage area and coverage structure (e.g. spatially limited indoor, short range systems, highly focused wireless backhauls or stretched wide area networks).
   Secondly, the dependency on the secondary spectrum can be described as the total dependence or partial dependence i.e. dependence for capacity enhancement.
2. **Spectrum Sharing Type:** Depending upon the scenario, spectrum sharing type can be selected. There can be overlay spectrum sharing in which interference control is ensured for enabling transmission by primary and secondary on the same frequency and at the same time.
   Other spectrum sharing type can be interweave operation in which, spatial spectrum opportunity is utilized i.e. secondary systems transmit on the frequencies which are not used by primary at that location at any time.
   In underlay operation the interference at primary is ensured below the noise floor.
3. **Licensing Type:** There can be three categories of licensing
   - Secondary Exclusive license: In this type, secondary devices do not share the secondary spectrum with other secondary users.
   - Secondary Sharing License: In this well-defined set of secondary systems can share the secondary spectrum
   - Secondary Spectrum Commons: In this case, any secondary system is allowed to operate on secondary spectrum opportunity.

ISSN: 2278 – 7798

Location Shivaji Nagar												
req. (MHz)	LOOP 1 (Signal Power Level In dBm)										Mean	Field Strength In uV/m
	1	2	3	4	5	6	7	8	9	10		
175	-84.9	-84.2	-84.5	-84.1	-83.8	-83.0	-80.6	-81.5	-80.0	-89.5	-83.6	62.45
469	-80.3	-85.3						-85.1	-87.1	-81.0	-83.8	164.5
535	-77.5	-80.3	-85.7	-75.2	-76.4	-79.4	-75.6	-79.2	-81.6	-83.5	-79.48	308.547
Freq. (MHz)	LOOP 2 (Signal Power Level In dBm)										Mean	Field Strength In uV/m
175	-87.9	-87.2		-85.1	-86.8	-86.9		-85.0	-86.0	-86.0	-86.41	45.45
469	-88.3	-76.1	-81.9	-76.2	-77.3	-86.5	-86.5	-81.8	-74.7		-81.06	225.51
535	-88.03	-82.6	-87.3		-83.4	-86.0	-86.0	-89.9	-82.2		-85.72	150.43
Freq. (MHz)	LOOP 3 (Signal Power Level In dBm)										Mean	Field Strength In uV/m
175	-81.4	-81.3	-82.2	-89.9	-86.2	-82.0	-82.7	-81.1	-80.3	-83.1	-83.05	66.91
469			-80.0	-78.2	-81.2	-82.3				-82.4	-80.88	230
535	-81.11	-76.6	-82.6	-81.8	-84.5	-85.4	-76.5	-79.4	-78.3	-77.5	-80.40	277.55
Freq (MHz)	LOOP 4 (Signal Power Level In dBm)										Mean	Field Strength In uV/m
175	-85.04	-85.6	-86.1	-89.2	-85.0			-89.9	-89.1	-87.8	-87.27	41.16
469	-80.13	-80.2	-83.8	-77.0	-75.7	-82.8	-83.3	-87.5		-83.7	-81.61	211.67
535	-82.55	-86.0	-85.8	-80.2		-84.8	-79.4	-87.8	-86.6		-84.19	179.41
Freq. (MHz)	LOOP 5 (Signal Power Level In dBm)										Mean	Field Strength In uV/m
175	-80.35	-81.0	-81.3	-89.8	-89.5	-80.8	-89.2	-83.3	-84.3	-84.9	-84.47	56.82
469				-71.6		-79.9	-73.4	-76.5		-73.9	-75.11	447
535	-88.03	-82.5	-85.4	-81.3	-79.0	-80.6	-79.0	-83.4		-81.8	-83.93	220.72
Freq. (MHz)	LOOP 6 (Signal Power Level In dBm)										Mean	Field Strength In uV/m
175	-83.53	-85.6	-86.1	-85.0			-89.2	-89.9	-89.1	-87.6	-87.05	42.22
469	-80.13	-80.2	-83.8	-87.1	-86.0	-82.8	-83.3	-80.3		-81.2	-82.79	184.78
535	-82.55	-86.0	-85.8	-80.2		-84.8	-79.4	-87.8	-86.6		-84.19	179.41
Freq. (MHz)	LOOP 7 (Signal Power Level In dBm)										Mean	Field Strength In uV/m
175	-80.35	-81.0	-81.3	-89.8	-89.5	-80.8	-89.2	-83.3	-84.3	-84.9	-84.48	56.75
469				-71.6		-79.9	-73.4	-76.5		-87.4	-77.80	328.22
535	-88.03	-82.5	-85.4	-83.4	-79.0	-80.6	-79.0	-83.4		-81.8	-82.61	215.2
Freq. (MHz)	LOOP 8 (Signal Power Level In dBm)										Mean	Field Strength In uV/m
175	-85.25	-85.0			-83.2	-82.5	-82.7	-86.1	-81.9	-84.1	-83.89	60.74
469							-76.6				-76.62	375.98
535	-87.81	-78.0	-84.8	-83.1	-82.6	-78.6	-76.6	-80.5	-82.0	-81.7	-81.61	241.46

Frequency(MHz)	Mean of Field Strength In uV/m
175	54.06
469	270.84
535	227.84

TABLE 3: READINGS & CALCULATION OF FIELD STRENGTH AT SHIVAJINAGAR

4. **Level of Cooperation:** We can categorize cooperation between primary and secondary as none, low and high. In the first case, opportunity detection relies entirely on spectrum sensing. Low level of cooperation can be achieved by geo-location data base for opportunity detection. The high level cooperation is achieved through close cooperation between primary and secondary devices. For example, primary transmitter transmits alert sequences before resuming the transmission so that secondary can withdraw its transmission.

IV. IMPLEMENTATIONS DETAILS

FIELD STRENGTH MEASUREMENT

For measurement of field strength I have used spectrum analyzer, antenna, p Laptop for interfacing and RF calculator Field strength affects the reception quality:

- ➢ Spectrum analyzer is a very important measuring Equipment.
- ➢ It can be used for IF, RF measurements for viewing spectrum and adjusting parameters related to spectrum.
- ➢ Also for Tracking of Satellite using either Beacon of satellite or carrier signal for Optimum Signal Received.
- ➢ Measurement of C/N (Important for Earth Stations).
- ➢ Can also be interfaced with Printer and Measurements can be preserved.

To calculate field strength, different locations considered, for each, 8 loops are considered. In each loop 10 readings I have taken at which for particular frequency, signal is detected. For each frequency signal power level in DB is taken, and then its mean is calculated. To measure field strength RF calculator is used for which signal power level, frequency and Antenna gain is required.

As we enter all this values in RF calculator we will get field strength in µv/m. With the help of this I have calculated field strength at Shiv1aji Nagar, Khed, Sinhagad, Lonavla. Here I mentioned readings taken at shivaji nagar where at frequency 175,469,535 signals is detected & by using spectrum analyzer peak values are considered for further calculations.

As I have considered 8 loops, for each loop field strength is calculated & as all loop execute for same frequency so that mean value is calculated Readings taken at shivajinagar is mentioned in table 3.

MEASUREMENT OF COVERAGE PLOT AND TVWS AVAILABILITY

I have plotted coverage plot at different region like Aurangabad, Bhusaval, Jalgaon, and Nasik. Multiple coverage plot is also taken for this region. Let us take a look one by one.

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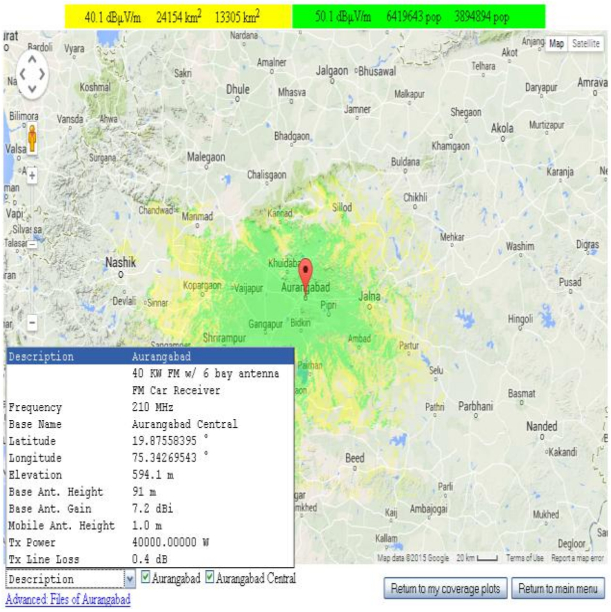

***FIGURE 1:* COVERAGE PLOT FOR AURANGABAD REGION**

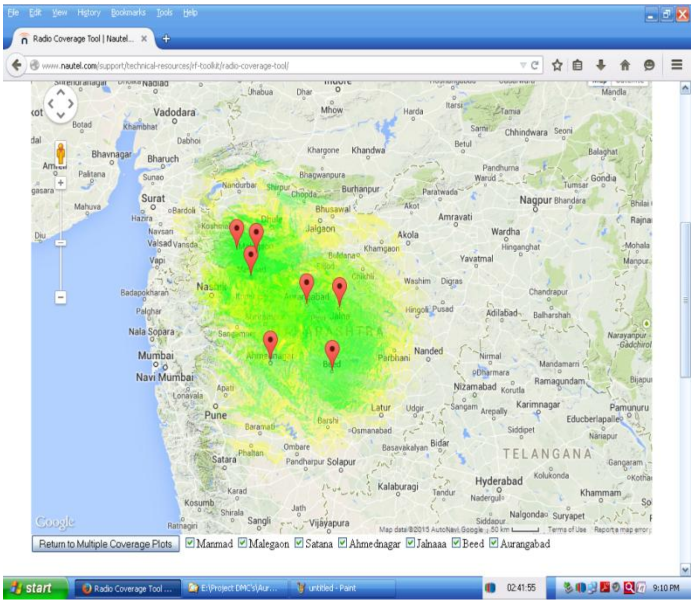

***FIGURE 2:* MULTIPLE COVERAGE PLOT FOR AURANGABAD REGION**

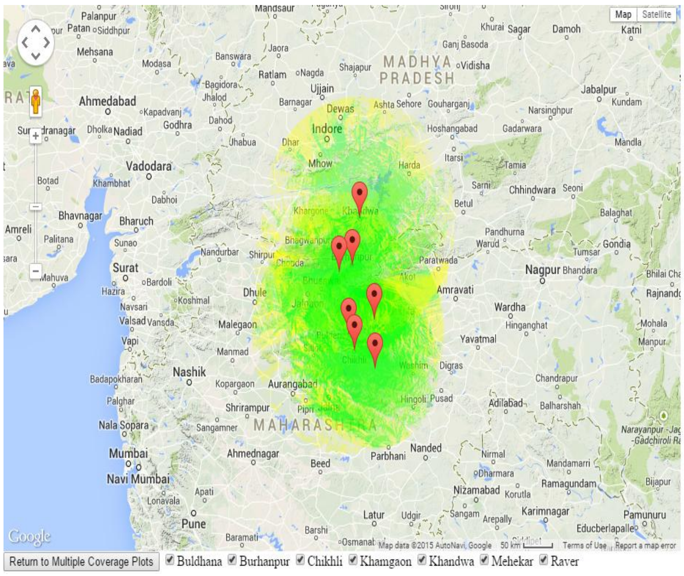

***FIGURE 3:* MULTIPLE COVERAGE PLOT FOR BHUSAVAL REGION**

Sr.No	Transmitter Name	Transmitter Type	Antenna Ht.(Meter)	Ch- No.	Frequency In MHz	Location		Elevation
						Latitude	Longitude	
1	Ahmed Nagar	LPT (100W)	100	9	203.25	19.11	74.75	675
2	Beed	LPT (100W)	100	10	210.25	18.98	75.76	512
3	Jalna	LPT (500W)	45	22	479.25	19.82	75.87	510
4	Manmad	LPT (500W)	45	30	543.25	20.25	74.43	579
5	Malegaon DDI	LPT(500W)	45	11	217.25	20.55	74.52	427
	Malegaon DDII	LPT (500W)	45	22	479.25	20.55	74.52	427
6	Satana	LPT (500W)	45	27	519.25	20.59	74.20	562

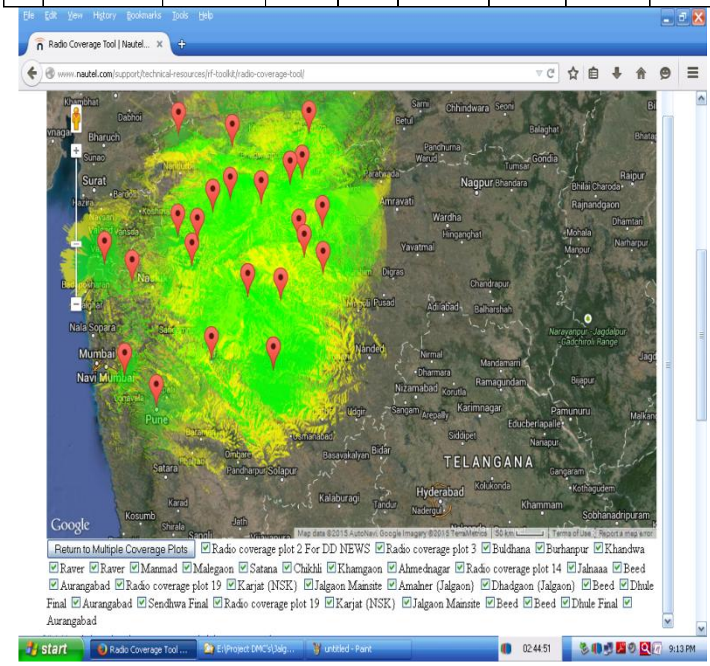

***FIGURE 4:* MULTIPLE COVERAGE PLOT FOR ALL FOUR REGIONS**

MEASUREMENT OF AVAILABILITY OF TVWS

For measurement of TVWS I have done simulation for which information of transmitter is required which I have collected from survey done at different DMC's like Aurangabad, Bhusawal ,Jalgaon, Nasik and from coverage plot mentioned above. The collected information is as follows:

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Sr.No	Transmitter Name	Transmitter Type	Antenna Ht.(Meter)	Channel- No.	Frequency In MHz	Location		Elevation
						Latitude	Longitude	
1	Amalner	LPT(100W)	30	10	210.25	21.04	75.05	186
2	Dhadgaon	LPT(100W)	45	7	189.25	21.82	74.21	348
3	Dhule Ddi Dhile Ddii	LPT(100W) LPT(500W)	100	12 30	224.25 543.25	20.90	74.77	264
4	Nandurbar	LPT(500W)	45	8	196.25	21.37	74.24	201.5

TABLE 4: AVAILABILITY MEASUREMENT FOR COVERAGE PLOT AURANGABAD REGION

Sr.No	Transmitter Name	Transmitter Type	Antenna Ht.(Meter)	Channel- No.	Frequency In MHz	Location		Elevation
						Latitude	Longitude	
1	Badlapur	LPT (500W)	45	9	203.25	19.15	73.75	30.7
2	Khopoli	LPT (100W)	45	8	196.25	18.78	73.33	76
3	Nasik DII Nasik DDI	LPT (100W) LPT (500W)	100	11 9	21.25 203.25	73.75 73.75	20.60 25.07	579.12 579.12
4	Sangamner	LPT (100W)	45	7	189.25	19.53	74.3	548
5	Shirdi	LPT (500W)	45	28	527.25	19.76	74.43	566
6	Silvasa	LPT (100W)	45	9	203.25	20.27	73.00	45
7	Junner	LPT (10W)	30	7	189.25	19.19	73.85	1100
8	Karjat	LPT (10W)	30	10	210.25	18.92	73.32	48

TABLE 5: AVAILABILITY MEASUREMENT FOR COVERAGE PLOT BHUSAVAL REGION

TABLE 6: AVAILABILITY MEASUREMENT FOR COVERAGE PLOT

Sr.No	Transmitter Name	Transmitter Type	Antenna Ht.(Meter)		Frequency In MHz	Location		Elevation
						Latitude	Longitude	
1	Buldhana	LPT (100W)	45	9	203.25	20.54	76.17	653.4
2	Burhanpur	LPT (500W)	60	7	189.25	21.31	76.22	252.7
3	Chikhali	LPT (100W)	45	7	189.25	20.35	76.26	600.3
4	Khamgaon	LPT (500W)	45	21	471.25	20.70	76.56	307.8
5	Mehkar	LPT (100W)	45	5	174.25	20.14	76.57	553.3
6	Raver	LPT (300W)	45	34	578.25	21.23	76.03	251.8
7	Khandawa	LPT(100W)	45	12	224.25	21.83	76.34	320

JALGAON REGION

TABLE 7: AVAILABILITY MEASUREMENT FOR COVERAGE PLOT

Sr.No	Transmitter Name	Transmitter Type	Antenna Ht.(Meter)	Ch- No.	Frequency In MHz	Location		Elevation
						Latitude	Longitude	
1	Buldhana	LPT (100W)	45	9	203.25	20.54	76.17	653.4
2	Burhanpur	LPT (500W)	60	7	189.25	21.31	76.22	252.7
3	Chikhali	LPT (100W)	45	7	189.25	20.35	76.26	600.3
4	Khamgaon	LPT (500W)	45	21	471.25	20.70	76.56	307.8
5	Mehkar	LPT (100W)	45	5	174.25	20.14	76.57	553.3
6	Raver	LPT (300W)	45	34	578.25	21.23	76.03	251.8
7	Khandawa	LPT(100W)	45	12	224.25	21.83	76.34	320

NASHIK REGION

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V. SIMULATION RESULT

TRANSMITTER	COVERAGE AREA FOR TRANSMITTER	POPULATION UNDER COVERAGE AREA	AVAILABILITY OF TVWS IN UNRESTRICTED AREA		AVAILABILITY OF TVWS IN RESTRICTED AREA	
			W.R.TO AREA	W.R.TO POPULATION	W.R.TO AREA	W.R.TO POPULATION
BHUSAWAL						
BULDHANA	52710	12837536	33.67	33.67	31.28	31.29
BURHANPUR	38682	9026861				
CHIKHALI	27477	6847298				
KHAMGAON	7687	21110664				
MEHKAR	27891	6375688				
RAVER	26461	6524994				
KHANDWA	48574	11632965				
AURANGABAD						
AHMAD NAGAR	23249	8954	30.85	31.05	33.3	33.27
BEED	43559	9722572				
MALEGAON	38650	5266921				
JALNA	42253	9830345				
MANMAD	20356	6400225				
SATANA	18773	5473231				

TRANSMITTER	COVERAGE AREA FOR TRANSMITTER	POPULATION UNDER COVERAGE AREA	AVAILABILITY OF TVWS IN UNRESTRICTED AREA		AVAILABILITY OF TVWS IN RESTRICTED AREA	
			W.R.TO AREA	W.R.TO POPULATION	W.R.TO AREA	W.R.TO POPULATION
JALGAON						
AMALNER	15805	4255812	31.01	31.03	32.92	32.96
DHADGAON	5764	1224481				
DHULE	22945	6158508				
NANDURBAR	11744	2578907				
SENDHWA	17026	3893519				
NASHIK						
BADLAPUR	2169	3271308	33.59	33.75	30.60	30.75
KHOPOLI	49	16515				
NASIK DII	1091	1104971				
NASIK DDI	295	4260				
SANGAMNER	898	238056				
SHIRDI	5499	1705395				
SILVASA	12944	3545006				
JUNNER	1288	315750				

ISSN: 2278 – 7798

VI. CONCLUSION

From measurement and availability of TVWS we conclude that currently only some of the TV channels are used, and also here we find the availability of TVWS, but actual white space scenario will be clear after complete digitization of the terrestrial TV transmission. It can be concluded that In India, TV spectrum is grossly underutilized and can be used for other services and also by TVWS technologies after digitization.

If we propose to use the white spaces for above type of deployment scenarios, it will influence the policy making of the regulator India. This proposal is made entirely in context to Indian scenario. In US large number of channels are used for terrestrial and interweave operation may not be much fruitful. On other hand in Indian scenario success is possible. The issues of choice of communication technology, frequency planning, opportunity detection mechanisms required have to be investigated and prototype should be tested in future time to come.

REFERENCES

1) Office of the Registrar General and Census Commissioner, Ministry of Home Affairs, Govt. of India, http://censusindia.gov.in/Census_And_You/area_and_population.aspx

2) R Chandrashekhar, Secretary, Department of Telecommunication, and Chairman, Telecom Commission, "Connecting the Panchayats in the country" an exclusive interview with eGov magazine.

3) Dimitris Makris, Georgios Gardikis and Anstasios Kourtis, "Quantifying TV White Space Capacity: A Geolocation-Based Approach, IEEE Communications Magzine: Topics in Radio Communications, September 2012.

4) Zander Jens, Sung Ki Won, Nekovee Maziar, Kronander Jonas, Kim S-L and Achtzehn Andreas, 'QUASAR scenarios for white space assessments and exploitation" URSI, EMC Europe conference. Wroclaw, Poland. September 13–17 2010.

5) Nekovee M, Ispwich, "Quantifying the Availability of TV White Spaces for Cognitive Radio Operation in the UK, Communications Workshops, 2009.

6) Telecom Regulatory Authority of India, 2007, Consultation paper on Issues Relating to Mobile Television Service, Paper No. 9/2007.

7) Jonas Kronander, MaziarNikovee, Jens zander, Ki Won Sung, Seong-Lyun Kim and Andreas Achtzehn, " QUASAR Scenrios for white Space Assessment and Exploitation" QUASAR Project, Wireless@KTH, KTH Royal Institute of Technology, Stockholm, Sweden.

ISSN: 2278 – 7798