Performance Evaluation of MM-Waves by Adopting Cognitive Radio under the Rain Fading

[1]M. Ajay Kumar, [2]N.Rajesha
[1]Research Scholar, Dept of ECE, Shri JJT University, Jhunjhunu-01
[2]Dept of ECE, Malla Reddy Institute of Engineering and Technology, Hyderabad-14

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Abstract:
In modern wireless-networks, the frequency bands of spectrum are licensed to the users for effective utilization. This sort of policy assures the licenses but it leads to under-utilization of spectrum management. The effective solution for this type of issue is effective spectrum-management policies, and the unlicensed are referred as secondary users, these secondary users can access the spectrum bands, when the bands primary users are unused. This is attained by proper monitoring of spectrum which is termed spectrum sensing mechanism based on the energy spotting techniques. The spectrum sensing is affected by time and spatial characteristics of radio frequency channel which depends on operational frequency and local environment. For the frequencies greater than 10GHz the channel is influenced for path-loss by the tropospheric attenuation, majorly by rain-fading. In this research work, we represent a systematic model for the performance analysis of energy spotting approach for the millimeter waves.

Keywords: *millimetre waves, cognitive radio, radio spectrum management, rain, radio channels, primary user, secondary user.*

I. INTRODUCTION

As demand of wireless and mobile communication operations are booming the serviceable radio frequency bands is getting packed day by day. Conferring to copious analyzers the allotted spectrum (licensed-spectrum) is not exploited perfectly by reason of stable allocation of the spectrum. It has turned into most challenging to spot the idle bands either for arranging a new utility or to intensify the existent one.

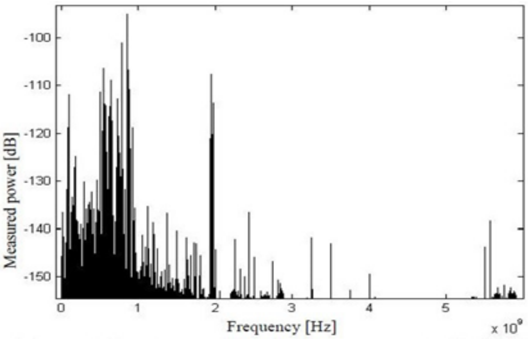

Fig 1: Spectrum Utilization (3)

In virtue to conquer these sorts of obstacles we adapted the “Efficient Management of Spectrum-” whichever enhances the exploiting of RF-spectrum. CR majorly works on Spectrum-management that dynamically clarifies the problem regarding radio-spectrum under usage in wireless and mobile transmissions in preferred-way. This compelling radio grants an eminently decisive communications [6]. Here, the un-licensed subscribers (SUs) are admitted to utilize the idle RF-bands of licensed subscribers (Primary users)[4]-[7].The Cognitive-radio alters its transposable parameters alike has operating-frequency, networking, protocols and wave forms etc., dependent on intercommunication with conditions it promotes.

In this research, we adopted mm-waves for communication purpose because they have large bandwidth, low interference and higher resolution for high data transfer.

Modern technology has increased effective bandwidth applications for everyday mobile communication. Traffic in wireless information seems to get predictability high in the next 20 years and stands as one of the concerning things to be looked upon. To face this, one of the best solutions is to adapt to a nonconventional spectrum that is capable of providing adequately large amount of bandwidths, preferably mmWaves with frequency range of 30GHz to 300GHz, that has bought it into consideration. Following are few points on why mmWaves are highly advantageous over other wireless technologies.

- **High bandwidth:** The carrier frequency of mmWaves is 30-300GHz, which is efficiently high than any present technologies and this gives access to ample amounts of spectrum that is up to 270GHz.
- **Small symbols:** Due to the short wavelength of mmWaves, the devices have the capability of adjusting large antenna array in usual physical space.
- **Narrow beams:** As large antenna arrays are adjusted together in the usual antenna size, the formed beam is narrower than usual which in turn paves way for various other applications.

II. mm WAVE CHARACTERISTICS

Now that we are advancing towards the next generation of cellular communications, Millimeter wave propagation characteristics stand as a promising design for upcoming 6G to 8G. Figure 1 gives the description of mmWave propagation characteristics.mm-Waves are known to have high value of path loss due to which it gives a restricted coverage, making it a best option for indoor wireless communication and minimal area outdoor communication as well. Whilst looking at the positives, it is important to consider other factors like distinct attenuation losses alike such haze, dry air, rain and vapor that might stand a challenge for mm-wave frequencies along with interference, rapid channel fluctuations, mobility etc.

These limitations result in the limitation of coverage, so there is a requirement for techniques that would make mmWaves adaptive considering the factors such as foliage loss, free space loss, path loss, fading and sensitivity to blockage. And on further study, the following were listed out as propagation issues of mm Waves:

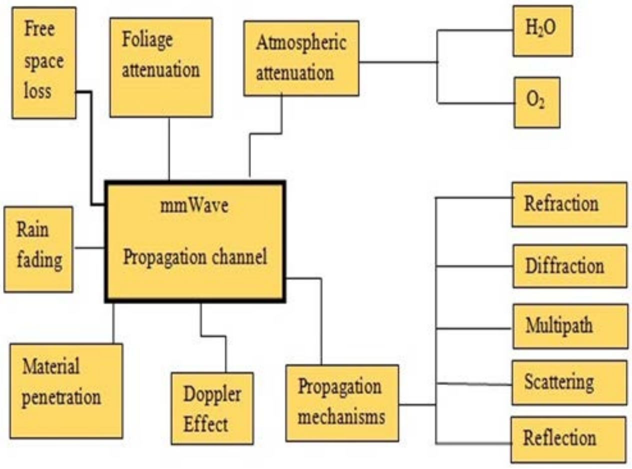

Fig 2: mmWaves propagation characteristics [22]

A. Path loss

Path loss or path attenuation defines the drop in the transmitted power-density of EM wave due to its propagation in free space. It can be determines as:

$$PL(dB) = 10log_{10}\frac{P_{tx}}{P_{rx}}$$

Path loss is usually calculated in decibels.

B. Fading

i. Large scale fading

Large scale fading is the variability of signal power transmitted over a large distance, averaged over regular wavelength intervals. Determination of path loss leads to further determination of large-scale fading as it is one of its characteristics.

$$L(d) = P_{tr} + A_{tr} + A_{re} - P_{re}(d) - L_o[dB]$$

A_{tr} and A_{re} are the transmission gain and receiver gain in dBi, and P_{tr} and P_{re} are the transmitter and receiver power respectively in dBm, and L_o gives the link loss of the mm-wave in Db.

ii. Small scale fading

Small-scale fading refer to the fast changes/fluctuations of phase and amplitude of radio waves while transmitted over a small area or for a minute time period. It also describes the multipath delay of the said signal. Path loss can be calculated by various models developed to fit the right environment and transmission space, as given below

P_L (f_c, d) [dB] = FSPL (f, 1 m) [dB] + 10nlog$_{10}$ (d) + A_{Tr} [dB] + $\delta\tau$ CI

Where d ≥ 1 m

whereas fc is carrier-frequency in GHz, d is the distance of transmission, as well as the path-loss exponent (PLE) is given as n, AT is the attenuation, $\delta\tau$ CI is a zero-mean Gaussian random variable in which τ is standard deviation in dB, Moreover FSPL (f, 1 m) interprets the free-space path loss in dB at a transmission distance of 1 m. Attenuation can be further given as

$$A_T \text{ [dB]} = \alpha \text{ [dB/m]} \times d\text{[m]}$$

and it is represented as dB/m for range in frequency of 1GHz to 100GHz for scattering coefficient α.

III. RAIN-INDUCED FADING

Heavy rains can have a drastic effect on millimeter wave causing high attenuation. High rainfall at tropical regions reaches up to 100mm/h increasing the attenuation range to 30dB/km. Cellular communication has been predicted to have radii of 200m according to research in UMi (urban-microcell) propagation at millimeter-wave.

Atmospheric attenuation can be ignored for short lengths whilst considering the fact that the measurements were taken at a temperate region with mild rainfall.

But in case of regions with heavy rainfall, rain attenuation will be an obstruction for implementation in upcoming generations of cellular mobile communications. This leads to the necessity of channel characterization for all atmospheric conditions so as to find ways for predicting rain fade before-hand for diverse frequency ranges of mm-Waves.

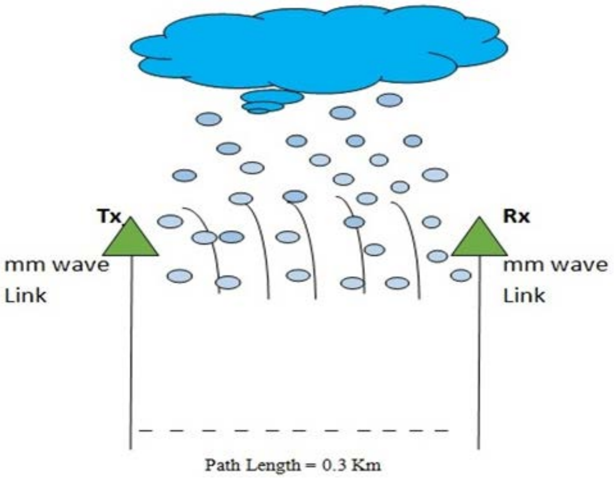

Fig 3: Rain attenuation[22]

A. Measuring attenuation due to rain

If we take a 300m link considering horizontal polarization, path attenuation can be obtained by taking the difference of radio signaling link ($RSL_{clearsky}$) for clear sky to that of radio signaling link (RSL_{rainy}) during rain. That is,

$$\text{Attenuation} = RSL_{\text{clearsky}} - RSL_{\text{rainy}}$$

If we measure the rain attenuation of signal with regards to free space, the received power through disturbance free path, excluding the multipath elements, can be given as

$$P_{re}(dBm) = P_{tr} + G_{tr} + G_{re} - 20log_{10}\frac{4\times\pi\times d}{\lambda} - P_{loss}(rain)$$

Where power transmitted is given as P_{tr}; transmitter gain as G_{tr}; receiver gain given as G_{re}, 'λ' wavelength and path loss P_{loss}, is to estimate the attenuation due to rain.

IV. CONCEPTION OF COGNITIVE RADIO

A. Spectrum-sensing

Spectrum sensing is the utmost crucial in the mechanism of cognitive-radio as its intelligence to sensibility and familiar in parameters relevant to attributes of radio channel. The mechanism of spectrum-sensing detects the existence or inexistence of PU signal in scheme of cognitive radios [6] this factor permit secondary user to admit un-occupied spectrum bands. The elemental essence of sensing a spectrum is typical binary hypothesis-testing issue.

H_0: Inexistence of primary user
H_1: Existence of primary user

Concurrently the data of input is measured in spectrum-sensing is inclined by [4]-[5].

i. Detection-Possibility (P_{dt}) that determines the possibility of secondary user spotting which the compelling.
ii. False alarm-Possibility (P_{fa}) that measures the SUs possibility, insisting that incumbent, is existent in formal spectrum, while the typical spectrum is free.
iii. Miss-detection Possibility, that access the secondary-user probability that declares the frequency-spectrum is free the fact is there is in incumbent present.

$$P_{de} = P\ (\text{decision} = H_1) = P(Y)$$
$$P_{fa} = P\ (\text{decision} = H_0) = P(Y)$$

Whereas Y is t decision statistic [5].

The spectrum sensing is classified into three groups al

i. **Transmitter-detection:** The spotting is dependent on signal in distinction to initial transmitter over the local interpretation of the SUs.
ii**. Cooperative-detection**: The SUs allots their sensing data and makes decision for precise and better Spotting.
iii. **Attenuation-dependent detection**: The conventional Spotting will utilize the interference-temperature pattern. And three commonly used distinct approaches in transmitter spotting are matched-filter approach, cyclostationary detection pattern and energy-Spotting method. The most transparent techniques which spots the inexistence and existence of PUs depends on energy of observed-signal is method of energy-spotting [2]. But, for matched-filter pattern, not needed any prior-data from cognitive PUs.

B. Energy-Spotting Method

The typical energy-spotting is the detection approach which utilizes the energy detector to spot the PU-signal is present or not in radio spectrum. This method has compelling factors to sense the signals in spectrum, in point of view it has the unbiased computational complexities, and also it is used in domains of frequency and time.

Energy spotting approach is essential of data regarding the Gaussian-noise within the band to determine the functions of detection[4]. As comparable to the conventional matched-filter, cyclostationary and energy-spotting methods necessary of priori-data of PUs to perform dynamically, and it is such complex/difficult to appreciate in practical by considering PUs problems in distinct cases. This sort of detection is not so optimal but the implementation is simple, for that reason it is adapted extensively. By comparing the output the sensing/spotting is easily done with the cutting range (threshold) which is based on conventional noise-factor. In energy spotting technique, firstly, the input signal has to filter with a BPF to choose the typical bandwidth [9] and the signal is squared along with integrated through a noted interval. The integrator is computed holds to decision-threshold to analyze the vacant band availability.

C. Block Schematic

The flow of the energy-spotting pattern is in fig 2. In below approach, the signal has to pass through the pre-noise filter of bandwidth ‘W’ as well as integrated over-time interval and outcome from integrator is then correlated to pre-determined threshold [3]. From this comparison, analyze the absence or existence of cognitive primary user. The value of threshold can set variable or fixed dependent on channel-conditions

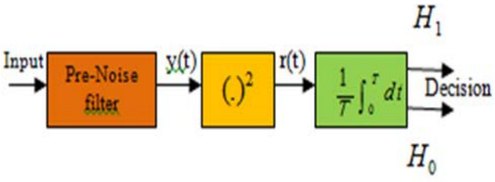

Fig 4: Spectrum sensing mechanism

The conventional detection is analysis of subsequent in two of the hypotheses

H_0 : The x(t) is input and noise alone:

a) $x(t)=m(t)$
b) $F[m(t)]=0$
c) The spectral-density of noise = M_{O2} (two sided)
d) Range of noise = w cycles-per second

H_1: The x(t) is the input-signal and noise:

a) $x(t) = m(t)+ r(t)$
b) $F[m(t) + r(t)] = r(t)$

The $q(t)$ is acknowledged-signal takes the form

$$q(t) = r(t) + m(t) \qquad (1)$$

The acknowledged-signal is initially pre-penetrated by optimal BPF with the conventional transfer-function.

$$H(f) = \begin{cases} \frac{2}{\sqrt{M_{01}}}, & |f - f_c| \leq w \\ 0, & |f - f_c| > w \end{cases} \qquad (2)$$

To limit the power of average-noise as well as to dispose the variance of noise and filter output is integrated and squared through a interval of time T to certainly produce an measure of received-waveform energy. The outcome of typical integrator will accomplish has the statistic test of two typical hypotheses H_1 and H_0

Conferring to typical sampling-theorem, the process regarding estimation of noise may be intended as [5].

$$\mathrm{m(t)} = \sum_{i=-\propto}^{\propto} n_i \mathrm{Sinc}\,(2Wt\text{-}i) \qquad (3)$$

Whereas

Sinc(w) = $\frac{Sin(\pi w)}{\pi w}$ and n_i = n $(\frac{1}{2W})$, one can conveniently reviewed that ……………

$$\int_{-\propto}^{\propto} \sin c(2Wt - k)dt = 1/2W, \; i = k = 0 \qquad (4)$$

We know that

$$\int_{-\propto}^{\propto} n^2(\mathrm{t})\mathrm{dt} = \frac{1}{2W} \sum_{i=-\propto}^{\propto} \eta_i^2 \qquad (5)$$

Accomplished an time-interval (0, T), m(t) is noise-energy can be proximate by the definite-entity of $2TW$ term has [5]

$$\mathrm{n(t)} = \sum_{i=1}^{2TW} \eta_i \,\mathrm{Sin\ c(2Wt - i)},\ 0< t < T \qquad (6)$$

Identically, energy/power in instance regarding duration "T" is proximate by the $2TW$ terms regarding right-handed side:

$$\int_0^T \eta^2\,(\mathrm{t})\mathrm{dt} = \frac{1}{2w} \sum_{i=1}^{2u} n_i^2 \qquad (7)$$

Wherein u = TW. We presume that W and T are preferred to confine to values of integer [3]

If we define

$$n_i = \frac{\eta_i}{\sqrt{N_{01}\ W}} \qquad (8)$$

Wherein N_{01} is the one-sided conventional noise-power.

Then

$$\varphi = \sum_{i=I}^{2u} \eta_i^2 \qquad (9)$$

φ can view as sum of squares of the "2u" typical Gaussian-variants with unit variance and zero mean. Accordingly, Y ensues a noted chi-square (χ^2) dispersion with the 2u-degrees of freedom and the identical approach as practiced when signal-s(t) is existing with substitute of $n_i + s_i$.

The statistic decision φ in this specific case will be conventional non-central χ^2 dispersion with the 2u-degrees of freedom as well as a parameter of the non-centrality is 2λ [6]. Subsequent short-hand representations noticed in the early part of the section and can represent the conventional decision-statistic as the possibility of density-function of the "φ" may written as

$$f_r(y) = \left\{\frac{1}{2} \left({}^{y}\!/_{2y}\right)^{\frac{u-1}{2}} e^{{}^{2y+y}\!/_{2}}\right\} \qquad (10)$$

Wherein ɼ (.) is function of gamma. The possibility of false alarm and detection can widely figure out by[1]

$$P_d = \Pr(\varphi > \vartheta | H_1) \quad (11)$$
$$P_f = \Pr(\varphi > \vartheta | H_0) \quad (12)$$

Wherein "ϑ" is final-threshold regarding typical local detector for making a decision whether the cognitive PU present or not.

$$P_f = \frac{\boldsymbol{\varphi}\,(\boldsymbol{u}\,{}^{\boldsymbol{\vartheta}}/_{\boldsymbol{2}})}{\boldsymbol{v}(\boldsymbol{u})} \quad (13)$$

Thence

$$\boldsymbol{P_d} = \boldsymbol{Q}_{\boldsymbol{u}(\sqrt{2\gamma}\sqrt{\vartheta})} \quad (14)$$

Whereas γ figures out the SNR moreover Q_u is hypothesized Marcum.

V. CHALLENGES OF RESEARCH

Conventionally compressed sensing has auspicious wide-band sensing approach in cognitive co-operative sensing. Nevertheless, it has a lot of wide research challenges:

A. ***Near-far-issue***: *Due to sampling. Nyquist-rate as well as inadequate sum of the samples, a incapable cognitive PU-signal with nearby the capable signal cannot be correctly reconstructed for wide-band sensing of spectrum.*

B. ***Hypothesis-testing***: *In typical sensing of the spectrum, the mathematical hypothesis-testing has conventionally carries out to analyze the outcomes of sensing for decision making with respect to cognitive PU presence. In this particular sub-section, we suggested a hypothesis-testing system generally used in sensing of spectrum and the hypothesis-testing patterns alike as GLRT (Generalized likelihood ratio test) as well as SPRT (Sequential-probability ratio test).*

VI. SIMULATION RESULTS AND ANALYSIS

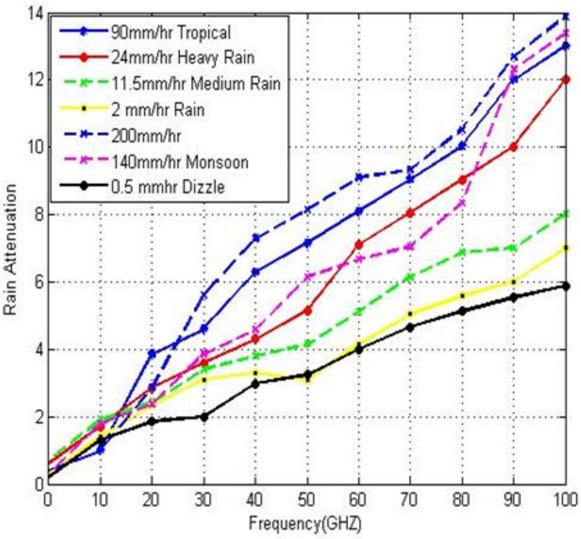

Fig 5: Rain attenuation w.r.t mmWave frequencies

The above figure clearly interprets the signal path loss in different scenarios with respect to wireless channel measurements, at 200 mm/hr rain; there is huge interference and the noise level increases and signal strength decreases spontaneously and at 0.5 mm/hr drizzle there is less fading of signal, and also the figure 5 indicates the rain attenuation at different frequencies in various Atmospheric conditions and mm-Waves efficiency in uncertain conditions

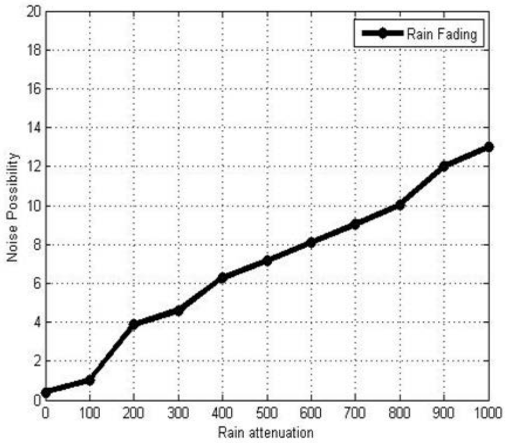

Fig 6: Noise possibility at Rain attenuation for mm-waves

The figure 6 shows that the noise level increases with increase in rain attenuation which adds unwanted interference, as analyzed in figure 5 the distinct weather conditions in atmosphere and rain can cause fading in signal, can refer as rain fading.

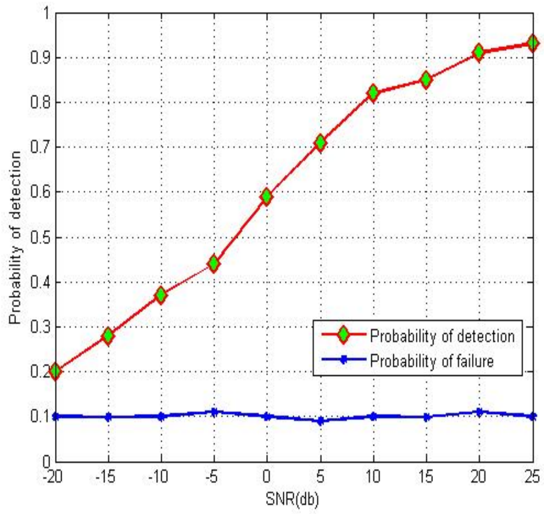

Fig 7: Probability of detection at different SNR

The outcome as implemented in MATLAB version R2017a concealed by AWGN channel and usage of receiver-characteristics (ROC) determination regarding signal-detection theory to define the efficiency of energy-spotter and it is an ideal-technique is to specify the trade-off among the possibility of detection (P_{dt}) along with the probability of failure (P_{fal}). The Fig 7 illustrates the spectrum-sensing regarding distinct SNR under the AWGN-channel. The outcome carried out to specify the pre-determined analysis of detection possibility under distinct number of the SNR. Wherein P_{fal}=0.1 as well as bandwidth-factor be appropriated for typical simulations. SNR is suitable for values -20dB to 25dB, the above figure illustrates the detection performance which varies on the SNR and the detection possibility taken 0.2 to 1db, it compellingly increases till -25db, and probability of failure decreases with increase in detection probability.

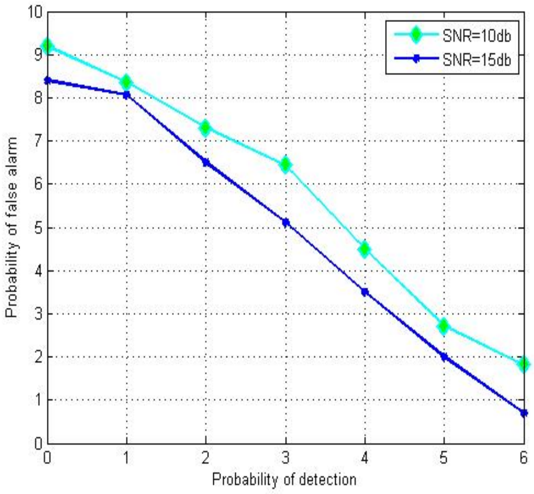

Fig 8: Probability of false alarm and detection at specific SNR

The fig 8 illustrates the efficiency of energy spotting method in spectrum sensing mechanism by varying the false alarm and detection possibilities at distinct SNR rates; the false alarm possibility declines with increase in detection possibility at SNR=10 & 15db; this increases the effectiveness of sensing method by decrease of sensing errors which reduces the efficiency and by this the spectrum usage is quite increased with utilization of vacant frequency bands.

VII. CONCLUSION

In this research paper, we reviewed the mm-waves communications and still there exits several issues that to be solved in future, For design of hardware for mm-Waves propagation the high gain antenna arrays are proposed with cognitive radio network. The co-operative spectrum-sensing is represented to boost the typical detection-accuracy. Composition of suitable process of detection mechanism at local-sensing together with suitable combining-technique at fusion centre advances overall detection-accuracy regarding CRNs. By considering the simulation outcomes, it has confirmed that the suggested detection scheme increases the performance of detection, diminishes attenuation among the cognitive SUs and PUs and decreases the conventional sensing error moreover increases the usage of spectrum. These methodologies can carry out in distinct fading conditions as well as performance can estimate. Under the uncertainty of noise , real-noise bounds can be determined.

REFERENCES

1. Ravi Verma, Arunanshu Mahapatro, "Cognitive Radio: Energy detection using wavelet packet transform for spectrum sensing" in communications; IEEE 27-28 Feb. 2017.
2. A Tony Cladia ; S Esakki Rajavel, "Optimizing Spectrum Sensing For Energy Efficient Cognitive Radio Sensor Networks", 2018 International Conference on Smart Systems and Inventive Technology (ICSSIT), IEEE proc.
3. "A Framework for Application Specific Wireless Sensor Platform", Proceedings of Second IEEE International Conference on Electrical, Computer and Communication Technologies, Feb 2017, Volume 2, pp 634-641, ISBN: 978-1-5090-3239-6.
4. S. Haykin, D. Thomson, and J. Reed, "Spectrum sensing for cognitive radio, "Proceedings of the IEEE, Invited Paper, 97(5) (2009) 849-877.
5. M. Filo et al "Cognitive pilot channel: Enabler for radio systems coexistence," in Proc. of Second Int. Workshop on Cognitive Radio and Advanced Spectrum Management, Alborg, Denmark,(2009)1-5.
6. Kwang-Cheng Chen, Irving T. Ho," Cognitive Radio Networks", CTiF Workshop 2007.
7. Joseph Malkevitch, American Mathematical Society, "Rationality and Game Theory", 2010.
8. D. Srikar, S. Anuradha; Twelve port MIMO antenna with polarisation diversity for cognitive radio applications, Electronics Letters (Volume: 55 , Issue: 22 , 10 31 2019), ISSN: 0013-5194; Page(s): 1165 – 1168.
9. "Implementation of MANETs over 6LoWPAN", International Journal on Advanced Computer Theory and Engineering, June 2015, India, vol. 4, issue 4, pp 32-35, ISSN (Print): 2319-2526.
10. Ghasemi and E.S.Sousa, "Opportunistic spectrum access in fading channels through collaborative sensing," J.Commun.,(2)(2007)71-81.
11. Subhajit Chatterjee , Sreshtha Ray , Swaham Dutta , Jibendu Sekhar Roy, "Performance analysis of spectrum sensing in cognitive radio at low SNR environment" in communications; IEEE 28-29 April 2017
12. Mitola, J.(2000). Cognitive radio-an integrated agent architecture for software defined radio.Ph.D.thesis,Royal institute of Technology(KTH).
13. Thirasara Ariyarathna et al, "Dynamic Spectrum Access via Smart Contracts on Blockchain", 2019 IEEE Wireless Communications and Networking Conference (WCNC); IEEE proc.
14. Smriti, Chhagan Charan, "Double Threshold Based Cooperative Spectrum Sensing with Consideration of History of Sensing Nodes in Cognitive Radio Networks" in communications; IEEE 1-2 June 2018.
15. J. Samuel Romero-Peña ; Narcís Cardona; Applicability Limits of Simplified Human Blockage Models at 5G mm-Wave Frequencies, 2019 13th European Conference on Antennas and Propagation (EuCAP); IEEE proc
16. Atapattu.S, Tellambura.C and Jaing H 2011Spectrum sensing Via energy detector in low SNR. In Communicatioin (ICC), 2011 IEEE International Conference, pp.1-5.
17. M.Ajay Kumar, N.Rajesha, Anupama Deshpande "Cognitive Radio Network based on Energy Spotting Method with Enhanced Sensing Accuracy", IJITEE (International Journal of Innovative Technology and Exploring Engineering), (ISSN 2278-3075) Volume-8 Issue-12 (October, 2019) pp. 4257-4261
18. Euler Edson et al "Performance of Spectrum Sensing Based on Energy Detection for Cognitive Radios" in communications; IEEE 10-14 Sept. 2018.
19. Hurmat Ali Shah et al; "Reliable cooperative spectrum sensing through multi-bit quantization with presence of multiple primary users in cognitive radio networks", 2019 34th International Technical Conference on Circuits/Systems, Computers and Communications (ITC-CSCC); IEEE proc
20. M.Ajay Kumar, N.Rajesha, Anupama Deshpande "Declining of Sensing Errors in Cognitive Radio by Threshold Determination of Energy Spotting

Method", IJRTE (International Journal of Recent Technology and Engineering), (ISSN 2277-3878) Volume 8, Number 2S3 (July-2019) pp. 895-898.

21. Wang et al.., "Millimeter Wave Communication:A Comprehensive Survey" IEEE Communications Surveys & Tutorials, Vol. 20, No. 3, ISSN: 1553-877X, Third Quarter 2018.
22. Yong Niu et al, A survey of millimeter wave communications (mmWave) for 5G: opportunities and challenges, Wireless Netw (2015) 21:2657–2676; Springer Science+Business Media New York 2015.
23. Akyildiz et al, (2006), Next Generation/dynamic spectrum access cognitive radio wireless networks: vol.50,IEEE 2017-2159.