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Effect of High Altitude Aeronautical Platforms with Cognitive Relay for Radar Performance

Ashagrie Getnet Flattie
Network Division, Department of Engineering, Ethio-Telecom, Addis Ababa, Ethiopia
Email: edenashagrie@gmail.com

***Abstract*—Cognitive radio (CR) is a promising technology for improving the utilization of wireless spectrum resources. The key characteristic of CR system is that allowing unlicensed user to use licensed spectrum bands opportunistically without affecting their performance. The use of cooperative relay networks can help cognitive radios system to improve their utilization by reducing their transmit power. Here High Altitude Aeronautical Platforms (HAAP) cognitive relay are introduced in order to achieve cooperative diversity in the cognitive radar (CRs) system. This system typically consists of the Primary Radar, Target, the Cognitive HAAP Relays, and the Cognitive Controller. In this paper, the cooperative (Amplify and Forward AAF) strategy will be considered, which achieves diversity by using Maximal Ratio Combining (MRC). Performance metrics like probability of false alarm (Pf), probability of detection (Pd) and signal to noise ratio are evaluated. Matlab software simulations were carried out and the results illustrate that notable performance improvements compared to direct transmission (i.e., without HAAP cognitive relay assistance) are achieved by the proposed schemes, especially substantial performance improves with the increase of the number of HAAPs cognitive relay nodes.**

***Index Terms*—cognitive radio, cooperative protocol, HAAP, radar, energy detection, relay**

I. INTRODUCTION

Careful studies by Federal Communications Commission (FCC) reveal that most of the allocated spectrum experiences low utilization, either due to sparse user access or to the system's inherent deficiencies. To remedy this situation, legislators are easing the way frequency bands are licensed and used. In particular, new regulations would allow for devices which promise a low cost, highly flexible alternative to the classic single frequency band, single protocol wireless device [1], [2], such as cognitive radios, to become secondary or cognitive users [3]-[5]. The core technology behind opportunistic spectrum access "cognitive radio" [6], [7] use the "spectrum holes" for communications, cognitive radio networking to transport packets on top of cognitive radio links is a must to successfully facilitate useful applications and services [8], [9]. That is, it is necessary to dynamically detect the existence of signals of primary users [10].

In order to avoid interference to primary radar, a cognitive radio (CR) needs to efficiently and effectively detect the presence of the primary radar. CRs communicate over the same frequency band that has been allocated to the existing primary radars. However, many factors make the spectrum sensing problem complicated, such as low signal-to-noise ratio (SNR), little knowledge of primary radar and detrimental effects of fading and shadowing. To combat these impacts, cooperative spectrum sensing has been proposed to obtain the space diversity in multiuser CR networks. In cooperative spectrum sensing, each CR user receives the signals from the primary radars, independently makes its local decision, and then sends the local observation to the fusion center (FC). Next, FC makes a final decision and immediately responses to CR radars once primary signal has been detected [11]. Cooperative gains in an environment where shadowing is correlated, is limited by the cooperation footprint (area in which radars cooperate). In essence, a few independent users are more robust than many correlated radars [4].

In cooperative networks multiple copies of the source's signal are transmitted from source to destination with the help of cooperative relays and a direct signal is also transmitted from source to destination. Then any diversity technique for e.g. maximum ratio combining is used at the destination to reduce fading. Signal fading arising from multipath propagation is a particularly severe channel impairment that can be mitigated through the use of diversity [12], [13]. The key challenges faced with distributed implementation of cooperative MIMO system are: (1) node coordination in sending and receiving groups, (2) distributed space-time coding and carrier frequency offsets in senders, and (3) data combining in the destination [14], [15].

Radar theory has been a vibrant scientific field for the past decades. Radar is a remote-sensing system that is widely used for surveillance, tracking, and imaging applications, for both civilian and military needs [16], [17]. The radar system's tasks are to detect the existence of the target and to estimate its unknown parameters, e.g., range, speed, and direction [18]. These radars, however, are known to exhibit detection and range estimation problems, hence jeopardizing the promised parameter identifiability, higher sensitivity to detect slowly moving targets [19], [20]. Radar systems could fail due to lack of line-of-sign (LOS) returns (especially urban environment), interference from multipath signal

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reflections, and large and inconsistent returns (or clutter) from objects such as buildings [21]. The performance of radar systems is limited by target scintillations. The range to, and the orientation of, the target determines the amount of energy reflected from these scatterers, and small changes in range or orientation can result in a large increase or decrease in the amount of energy reflected from the target [22]. To overcome these problems, several efficient approaches and radar performance has extensively been investigated in the literature [23], [24]. For instance recent advances in multiple-input multiple-output (MIMO) and cognitive technologies can be applied [25], [26]. Cognitive radar is a relatively new concept to the radar community. Cognitive radar should be capable of performing intelligent signal processing at both the transmitter and the receiver based on its knowledge of the environment. In cognitive radio network, the radios continuously scan the radio spectrum and create spectrum usage report [27]-[30].

This paper attempts the cognitive and cooperative for conventional radar and high altitude aeronautical platforms (HAAP) system to obtain better performance. A possible solution is to use high-altitude platforms (HAPs) or high-altitude very long endurance (HAVE) vehicles in the stratosphere has been recently proposed, which are either airships or planes that will operate in the stratosphere, at an altitude of 17-22km above the ground. This unique position offers a significant link budget (line-of-sight Links) advantage compared with satellites and a much wider area of coverage than terrestrial using considerably less communications infrastructure than that required if delivered by a terrestrial network [31]. AHAP may be viewed as either a very low stationary satellite or a very tall radio mast. Wireless communications using HAPS have been proposed worldwide due to the many advantages of HAPS system over terrestrial and satellite systems since stratospheric airplanes are more reliable [32].

In this paper, HAAP relay cooperative communications strategy to maximize the radar performance in a cognitive system proposed. In cognitive networks, the primary radar should be protected as much as possible. This task is usually fulfilled through spectrum sensing. Thus sensing accuracy is important for avoiding interference primary radar. The idea is to utilize HAAP relay nodes to convey the signal transmitted from the primary radar to a cognitive coordinator, which will make estimation of the presence or absence of primary activities. In Cooperative Relaying, one of cognitive nodes is used to support signal transmission by using Amplify-And-Forward relaying mode. The transmitter detection based techniques, Energy Detection (ED) used for spectrum sensing. It has been seen that each transmitter detection technique has a Signal to Noise Ratio (SNR) threshold, below which these techniques fail to work robustly. Relays are assigned in cognitive radio networks to transmit the primary radar's signal to a cognitive coordinator. The cognitive coordinator uses an energy detector to make the estimation.

The rest of this paper is organized as follows: Section II describes the system model and cognitive relay, cooperative; energy detection technologies will be briefly reviewed. Section III reviews basic concept for HAAP and radar system such as, HAAP coverage, signal detection probability and Swerling case. Section IV verifies the radar performance of the proposed scheme by computer simulation. Finally, conclusions are given in Section V.

II. SYSTEM MODEL

In this section the proposed model illustrates. A typical primary radar transmitter, denoted by P, transmits its signal to a target and then the reflected signal transmit to HAAP cognitive relay(r) and direct to cognitive receiver, denoted by (d). During the first hop, the source terminal transmits to the relay. In the second hop, the relay terminal transmits the amplified signal from the first hop to the destination. It is crucial that presence of this primary radar be detected as soon as possible. Fig. 1 shows the system model considered in this paper, it consist s of n cognitive relays between the primary and the cognitive coordinator. The channel gains from primary user-i^{th} cognitive relay r_i, the primary – the cognitive coordinator and i^{th} cognitive relay r_i the cognitive coordinator are denoted by h_{pri}, h_{pd} and h_{rid}, respectively.

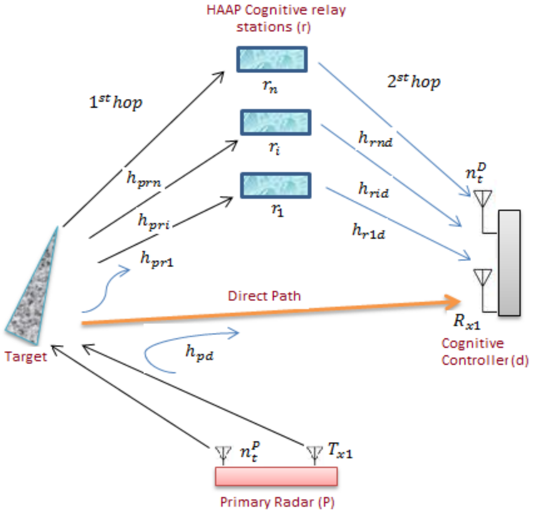

Figure 1. System model for cooperative HAAP cognitive multiple relay radar networks with cognitive controller.

A. Single Relay HAAP Station

A single HAAP cognitive relay continuously monitors the signal received from the primary radar. If a signal x is sent, the received signal y_r by the HAAP cognitive relay is given by

$$y_r = \sigma h_{sr} x + w_1 \tag{1}$$

where σ denotes the primary activity indicator, which is equal to 1 at the presence of primary activity, or equal to 0 otherwise, x is the transmitted signal drawn out of a modulation scheme such as BPSK, QPSK or MQAM from the primary radar, h_{sr} is the channel gain between the primary radar and HAAP relay, and w_1 is the additive Gaussian noise. The cognitive relay acts as amplify-and-forward relay (AF) protocol. The cognitive relay has a transmission power constraint and transmitted signal power from the primary radar denoted by E_r and E_p respectively. Thus, the amplification factor A_r, can be calculated as

$$A_r = \sqrt{\frac{E_r}{\sigma^2 E_p |h_{sr}|^2 + N_0}} \tag{2}$$

Considering y_d the received signal at the cognitive coordinator and defining as,

$$y_d = A_r y_r h_{rd} + w_o \tag{3}$$

where w_o is be additive, white and Gaussian (AWGN) with zero mean and variance α_w^2 added at cognitive centre. In the absence of coherent detection, the signal samples can also be modeled as Gaussian random process with variance α_x^2. A_r is the amplification factor.

The received signal at the cognitive coordinator follows a binary hypothesis [1].

$$\begin{cases} H_0 : y_d = w & \sigma = 0 \text{ (signal absent)} \\ H_1 : y_d = hx + w & \sigma = 1 \text{ (signal present)} \end{cases} \tag{4}$$

The binary hypothesis H_1 and H_0 represent the primary radar signalis present and absent respectively.

The total e2e (end-to-end) SNR for single relay station is given by

$$\gamma = \frac{1}{N_0}\left(\frac{E_p E_r |h_{pr}|^2 |h_{rd}|^2}{\Omega_{pr} E_p + N_0 \frac{E_r}{\Omega_{pr} E_p + N_0} |h_{rd}|^2 + 1}\right) \tag{5}$$

where h_{pr} and h_{rd} denotes channel coefficients of links from primary user to the cognitive relay and from the cognitive relay to the cognitive coordinator, respectively.

B. Multiple Relay HAAP Station

A multi-hop and multiple relay cooperative cognitive radio networks consider. All cognitive relays simultaneously receive primary radar's signal through independent fading channels. Each cognitive relay (say relay r) amplify the received primary signal. Thus, the amplification factor A_r, can be calculated as

$$A_{ri} = \sqrt{\frac{E_{ri}}{\sigma^2 E_p |h_{pri}|^2 + N_0}} \tag{6}$$

And forward to the cognitive coordinator. All the relay stations use time division multiple access (TDMA) based protocols for forwarding the received signal to cognitive centre, which performs optimal maximum-ratio combining (MRC) of the signal received from the source node. In the following, let γ denote the (overall) MRC total e2e output SNR per information bit at the destination node.

$$\gamma = \frac{1}{N_0}\left(\sum_{i=1}^{N} \frac{E_{pri} E_{rid} |h_{pri}|^2 |h_{rid}|^2}{\Omega_{pri} E_{pri} + N_0 \frac{E_{rid}}{\Omega_{pri} E_{pri} + N_0} |h_{rid}|^2 + 1}\right) \tag{7}$$

where $|h_{pri}|$ and $|h_{rid}|$ are channel gain coefficients from primary user to relay stations and from relay stations to cognitive centre.

The received total signal SNR at cognitive centre for single HAAP relay station and direct link after the two hops is given by:

$$\gamma = \gamma_d + \gamma_r \tag{8}$$

$$\gamma = \frac{1}{N_0}|E_{pd}||h_{pd}|^2 + \frac{1}{N_0}\left(\frac{E_p E_r |h_{pr}|^2 |h_{rd}|^2}{\Omega_{pr} E_p + N_0 \frac{E_r}{\Omega_{pr} E_p + N_0} |h_{rd}|^2 + 1}\right) \tag{9}$$

The received total signal SNR at cognitive centre for HAAP multiple relay station and direct link after the two hops is given by:

$$\gamma = \gamma_d + \sum_{i=1}^{N} \gamma_r \tag{10}$$

$$\gamma = \frac{1}{N_0}|E_{pd}||h_{pd}|^2 + \frac{1}{N_0}\left(\sum_{i=1}^{N} \frac{E_{pri} E_{rid} |h_{pri}|^2 |h_{rid}|^2}{\Omega_{pri} E_{pri} + N_0 \frac{E_{rid}}{\Omega_{pri} E_{pri} + N_0} |h_{rid}|^2 + 1}\right) \tag{11}$$

Mathematically, if γ represents the instantaneous SNR, then is the average SNR

$$\bar{\gamma} \triangleq \int_0^{\infty} \gamma p_\gamma(\gamma) d\gamma \tag{12}$$

where $p_\gamma(\gamma)$ is the pdf of γ.

C. Outage Probability

The probability of the instantaneous error probability exceeding a particular value (or the probability of the output SNR, γ) at the destination [33]. The outage probability P_{out}, is given by

$$P_{out} = \int_0^{\gamma_{th}} p_\gamma(\gamma) d\gamma \tag{13}$$

Outage probability can be expressed as the probability that the mutual information of the channel falls below a particular rate at a given SNR. Mathematically

$$P_{out} = P_r[\gamma < \gamma_{th}] \tag{14}$$

D. Energy Detection

An energy detection approach is a common way of spectrum sensing to decide whether unknown signals exist or not. Fig. 2 depicts the block diagram of Energy Detector based spectrum sensing as an input the received signal waveform $y(t)$. First, the input signal is filtered with a band pass filter to select the bandwidth of interest. The output signal is then squared and integrated over the observation interval. Lastly, the output of the integrator is compared to a predetermined threshold to infer the presence or not of the primary signal.

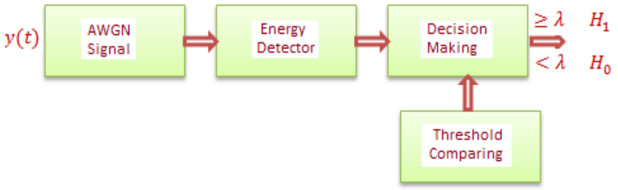

Figure 2. Energy detector

The total signal power (energy per unit time) is proportional to the average magnitude squared. The output signal V from the integrator is

$$V = \frac{1}{T}\int_{t-T}^{t} |y(r)|^2 \, dr \tag{15}$$

For the evaluation of the detection performance, the probabilities of detection P_d and false alarm P_f are given as follows [34].

$$P_d = P\{\text{decision} = H1\backslash H1\} = P\{y > \lambda\backslash H1\} \tag{16}$$

$$P_f = P\{\text{decision} = H1\backslash H0\} = P\{y > \lambda\backslash H0\} \tag{17}$$

where y is the decision statistic and λ is the decision threshold. The value of λ is set depending on the requirements of detection performance. Based on these definitions, the probability of a miss or miss detection is defined as $P_m = 1 - P_d = P\{\text{decision}=H0\backslash H1\}$. Sensing the environment, employing the most suitable filtering, detector algorithms and applying a consensus algorithm to produce a global detection decision [35].

III. BASIC CONCEPT FOR HAAP AND RADAR

A. *HAAP Coverage*

The HAPs concept takes advantage of the advancements in microwave power transmission developments associated with the modern Solar Power systems and High Altitude Powered Platform concepts. HAPs are designed to fly at altitudes of around 22km because the average wind speed in the stratosphere is minimal at altitude of about 20Km and at this altitude (which is well above commercial aircraft height), they can maintain a quasistationary position and support payloads [36].

In order to decide how much HAP is needed to provide the adequate coverage needed, we need to know the area covered by a single HAP. For a given platform altitude h, the diameter of the HAPS footprint can be computed using the formula:

$$d = 2R\left(\cos^{-1}\left(\frac{R}{R+h}\cos\theta\right) - \theta\right) \tag{18}$$

where R is the Earth radius (6378km), θ is the minimum elevation angle and the altitude.

B. *Detection Probability and False Alarm Probability*

The "detection probability" Pd is the conditional probability that, given that a signal is present, the signal-plus-noise falls within the range that will result in a "signal present" decision. A false alarm occurs whenever the noise voltage exceeds a defined threshold voltageVT, [37], [38].

Mathematically, these quantities are given by

$$P_d = \int_{VT}^{\infty} dvp\left(\frac{v}{s}\right) \tag{19}$$

$$P_{fa} = \int_{VT}^{\infty} dvp\left(\frac{v}{n}\right) \tag{20}$$

where VT is a chosen "threshold" voltage level, such that, if v(t) falls above that threshold, the decision will be "radar signal present" and if v(t) falls below the threshold, the decision will be "noise alone," and where p(v/s) and p(v/n) are the conditional PDFs of v given the condition "radar signal present" and "noise alone," respectively [39]. For Gaussian noise

$$P_{fa} = \frac{1}{2}\left[1 - \text{erf}(\widehat{V}_T)\right] \tag{21}$$

where $\widehat{V}_T = V_T/\sqrt{2\sigma_n}$=threshold voltage normalized to $\sqrt{2}$ times the root mean square (r. m. s) noise level and $\sqrt{|R|} = |s|\sqrt{2\sigma_n} = \frac{1}{\sqrt{2}}(\text{VoltageSNR})$, $u = \pm\sqrt{|R|}$ and $\text{erf}(x) = 2/\sqrt{2\pi}\int_0^{\infty} dy^{e-y^2}$=error function.

Considering that the radar signal is a sine waveform with amplitude A, then its power is $A^2/2$, $\text{SNR} = A^2/2\psi^2$ (single-pulse SNR) and $V_T^2/2\psi^2 = \text{in}(\frac{1}{P_{fa}})$, then

$$P_D = \int_{VT}^{\infty} \frac{r}{\psi^2} I_o\left(\frac{r^A}{\psi^2}\right) \exp\left(\frac{r^2+A^2}{2\psi^2}\right) dr = \varrho\left[\sqrt{\frac{A^2}{\psi^2}}, \sqrt{2\ln\left[\frac{1}{P_{fa}}\right]}\right] \tag{22}$$

Marcum define as Pd which equal 10

$$\varrho[\alpha, \beta] = \int_{\beta}^{\infty} \mathcal{E} I_o(a\mathcal{E}) e^{-(\mathcal{E}2+a2)/2} d\mathcal{E} \tag{23}$$

Q is called Marcum' Q-function [40], [41]. Many approximations for computing "(13)"can be found in the literatures. The very accurate approximation presented by North

$$P_d \approx 0.5\,\text{xerfc}(\sqrt{-\text{In}P_{fa}} - \sqrt{\text{SNR} + 0.5}) \tag{24}$$

where the complementary error function is:

$$\text{Erfc}(z) = 1 - \frac{2}{\sqrt{\pi}}\int_0^z e^{-v^2} dv \tag{25}$$

TABLE I. DIFFERENT CASES TO WHICH SWERLING MODELS APPLY SIMULATION ASSUMPTION

Model	k	Fluctuation		Scattere
		Scan-to-Scan	Pulse-to-Pulse	
Swerling Case I	1	√		Many Independent
Swerling Case II	1		√	
Swerling Case III	2	√		One dominant
Swerling Case IV	2		√	

C. *Detection of Fluctuating Targets*

When a target is present, the amplitude of the signal at the receiver depends on the target radar cross section (RCS), which is the effective scattering area of a target as seen by the radar. Target RCS fluctuations are often modeled according to the four Swerling target cases, Swerling case I to IV. These fluctuating models assume that the target RCS fluctuation follows either a Rayleigh or one-dominant-plus Rayleigh distribution with scan-to-scan or pulse-to pulse statistical independence [40]. They are summarized in the chi-square target models family by [42].

$$P_k(S) = \frac{1}{\Gamma(k)}\frac{k}{m_s}\left(\frac{kS}{m_s}\right)^{k-1}\exp\left(-\frac{kS}{m_s}\right), S \geq 0 \tag{26}$$

where $\Gamma(k) = (k-1)!$, $S = A^2/2\sigma^2$ is the target signal-to-noise power ratio (radar cross section), m_s is the average signal-to-noise ratio (mean cross section), $k = m_s^2/\,var[S]$, σ^2 is the noise variance, and A is the signal amplitude. Table I shows the different Swerling target models for different values ofk.

IV. SIMULATION RESULTS ANALYSIS

In this section, computer simulation results are presented to evaluate radar system with cooperative diversity in HAAPs cognitive relay networks under using different number of relay. The primary transmit signal interacts with one of the targets and the echo is corrupted by AWGN. The effect of the parameters, namely the estimated detection probability (P_d) , False alarm probability (P_f) , Swerling case I, II, III & IV and fluctuation loss are extensively investigated. In particular, the effectiveness of proposed scenario is studied through two and four relay application scenarios. In a cognitive radio system, each secondary system has a detection probability and a false alarm probability on a primary channel. The performance of the proposed scheme is verified by MATLAB simulation.

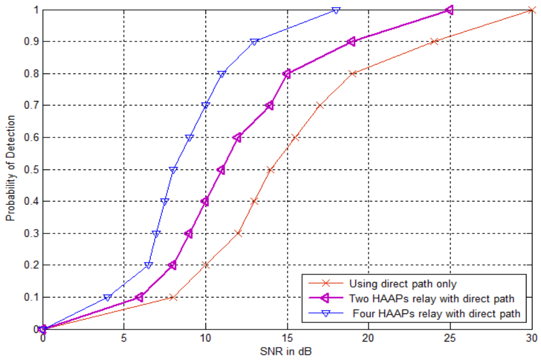

Figure 3. Probability of detection versus SNR (e2e) in different number of HAAPs cognitive relays.

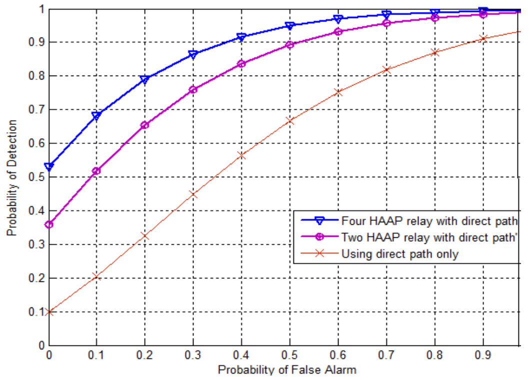

Figure 4. Probability of detection versus probability of false alarm (i.e., ROC curves)in different number of HAAPs cognitive relays.

Fig. 3 shows the probability of detection performance of the proposed cooperative spectrum sensing with HAAPs cognitive relay technique for various schemes: direct path, two HAAPs cognitive relay and four HAAPs cognitive relay. It is evident that signal detection through HAAPs cognitive relays in comparison with the signal detection through direct link, results in higher performance. In addition to this probability of detection is improved by using more number of HAAP relays, results in higher performance in radar system achieved using HAAPs cognitive relay. It can be seen that the required SNR is decreased as the number of relay increases. Considering that the above, we can conclude that cognitive radio (CR) in HAAPs relay system has a good potentially to improve the utilization efficiency of the radar spectrum in; addition to this cooperative communications can play a key role in the development of CR networks.

Fig. 4 shows the performance variations of probability of detection P_d with probability of false alarm P_f. From this figure it is clearly seen that, the number of cognitive relays as well as the direct path has a great impact on the probability of detection. It is shown that probability of detection increases for larger number of HAAPs cognitive relay. When signal detection is performed using 4 HAAPs cognitive relay and 2 HAAPs cognitive relay instead of using only a direct path signal, the probability of detection increases approximately 0.48 and 0.34 respectively comparing direct path for a probability of false alarm equal to 20%.

Next, we would like to evaluate the radar performance of the proposed fluctuation signal scheme by setting probability of detection (P_d) =0.7 (i.e., maximum allowable miss detection probability=0.3). In this values the required SNR 10dB, 13.5dB and 17dB in direct path only, two HAAPs relay and four HAAPs relay, respectively. The corresponding fluctuation loss Vs probability of detection in different Swerling case is shown Fig. 5, Fig. 6 and Fig. 7.

Fig. 5, Fig. 6 and Fig. 7 shows the probability of detection performance of the different number of HAAPs cognitive relay with four Swerling case. An important point to note here is that the probability of detection (P_d) and fluctuation loss are not linearly related. Thus increase in fluctuation loss does not imply an equivalent increase in probability of detection. A careful observation of Fig. 5, Fig. 6 and Fig. 7 indicates that the P_d increases with decrease probability of false alarm (P_f), or increase number of relay. It is shown that the best performance is achieved, when the proposed scheme used four HAAPs cognitive relay, for example when fluctuation loss equal to 4dB, P_d improve 9% and 7% in Swerling case I&II and III&IV respectively.

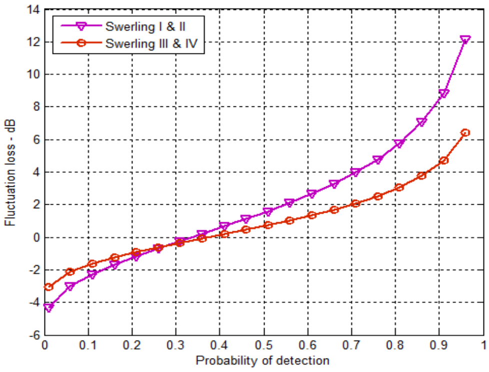

Figure 5. Fluctuation loss versus probability of detection using direct path signal with different Swerling case.

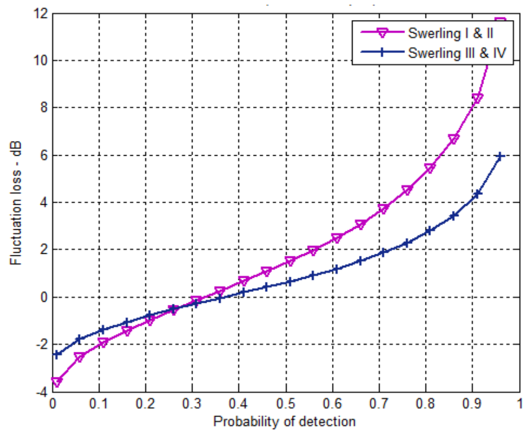

Figure 6. Fluctuation loss versus probability of detection usingtwo HAAPs cognitive relay and direct path signal with different Swerling case.

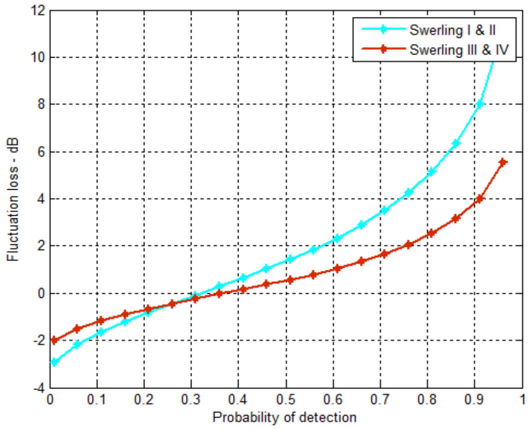

Figure 7. Fluctuation loss versus probability of detection usingfourHAAPs cognitive relay and direct path signal with different Swerling case.

V. CONCLUSIONS

In this paper, the performance of primary radar in single or multiple High Altitude Aeronautical Platforms (HAAP) cognitive relay scenarios proposed. This study has attempted to illustrate the effect of HAAP cognitive relay methods with cooperative protocol in radar system. In such scenarios, HAAP Relays are assigned in cognitive radar networks to transmit the primary radar's reflected signal to a cognitive coordinator. Some of the key concepts like HAAP cognitive relay, radar probability of detection, matched filtering and energy detection were delineated; special emphasis was given to cooperative and cognitive methods. The proposed methods provide effective technique to improve radar detection performance, while the false alarm rate is reduced by exploring spatial diversity at the expense of cooperation overhead. The performance of the radar system can be further improved through deploying more relay with different Swerling case.

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REFERENCES

[1] Z. Quan, S. Cui, and A. H. Sayed, "Optimal linear cooperation for spectrum sensing incognitive radio networks," *IEEE J. Select. Topics Signal Processing*, vol. 2, no. 1, pp. 28-40, 2008.
[2] B. A. Fette, *Cognitive Radio Technology*, USA: Newnes Publisher, 2006, pp. 130-140.
[3] N. Devroye, M. Vu, and V. Tarokh, "Achievable rates and scaling laws for cognitive radio channels," *EURASIP Journal on Wireless Communications and Networking*, vol. 2008, 2008.
[4] S. M. Mishra, A. Sahai, and R. W. Brodersen, "Cooperative sensing among cognitive radios," in *Proc. IEEE Int. Conf. Communications*, 2006, pp. 1658-1663.
[5] J. Mitola, "Cognitive radio: An integrated agent architecture for software defined radio," PhD Dissertation, KTH, Stockholm, Sweden, Dec. 2000.
[6] J. Mitola and G. Q. Maguire, "Cognitive radios: Making software radios more personal," *IEEE Personal Communications*, vol. 6, no. 4, pp. 13-18, 1999.
[7] Federal Communications Commission Spectrum Policy Task Force, "FCC report of the spectrumefficiency working group," Tech. Rep., Federal Communications Commission, Washington, DC, USA, Nov. 2002.
[8] N. Prasad, *Cognitive Radio Network Architecture*, Denmark: Center for TeleInFrastruktur Aalborg University Aalborg, Jul. 2000.
[9] A. Bency and S. Manikandan, "Selfish attacks detection in cogitive radio networks using CRV technique," *International Journal of Software and Hardware Research in Engineering*, vol. 2, no. 5, May 2014
[10] Y. Zeng and Y.-C. Liang, "Maximum-Minimum eigenvalue detection for cognitive radio," in *Proc. 18th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communication (PIMRC)*, 2007.
[11] H. Hu, Y. Xu, Z. Liu, N. Li, and H. Zhang "Optimal strategies for cooperative spectrum sensing in multiple cross-over cognitive radio networks," *KSII Trans. Internet and Info. Systems*, vol. 6, no. 12, pp. 3061-3080, Dec. 2012.
[12] J. N. Laneman, D. N. C. Tse, and G. W. Wornell, "Cooperative diversity in wireless networks efficient protocols and outage behaviour," *IEEE Trans. Inf. Theory*, vol. 50, no. 12, pp. 3062-3080, 2004.
[13] S. Alam and S. H. Gupta, "Performance analysis of cooperative communication wireless network," *International Journal of Electronics and Communication Engineering and Technology (IJECET)*, vol. 3, no. 2, pp. 301-309, Sep. 2012.
[14] Y. Fu, L. Yang, and W. Zhu, "A nearly optimal amplify-and-forward relaying scheme for two-hop MIMO multi-relay networks," *IEEE Communications Letters*, vol. 14, no. 3, Mar. 2010.
[15] H. Shen, H. Yang, B. Sikdar, and S. Kalyanarama, "A distributed system for cooperative MIMO transmissions," in *Proc. IEEE Global Communications Conference*, Los Angles, USA, 2008, pp. 1-5.
[16] S. Haykin, "Cognitive radar: A way of the future," *IEEE Signal Processing Magazine*, vol. 23, no. 1, pp. 30-40, 2006.
[17] Y. Nijsure, *et al.*, "Information-Theoretic algorithm for waveform optimization within ultra wideband cognitive radar network," in *Proc. IEEE ICUWB*, Sep. 2010, pp. 1-4.
[18] E. Fishler, *et al.*, "Spatial diversity in radars-models and detection performance," *IEEE Trans. Signal Process.*, vol. 54, no. 3, pp. 823-838, Mar. 2006.
[19] B. Garcia, M. J. Sanmartin-Jara, F. Perez-Martinez, and J. A. Retamosa, "Radar sensor using low probability of interception SS-FH signals," *IEEE Aerospace and Electronic Systems Magazine*, vol. 15, no. 4, pp. 23-28, 2000.
[20] K. W. Forsythe, D. W. Bliss, and G. S. Fawcett, "Multiple-Input multiple output (MIMO) radar: Performance issues," in *Proc. 38th Asilomar Conference on Signals, Systems and Computers*, Pacific Grove, CA, Nov. 2004, pp. 310-315.
[21] B. Chakraborty, *et al.*, "Multipath exploitation with adaptive waveform design for target tracking in urban terrain," in *Proc. International Conference on Acoustics, Speech, and Signal Processing*, Dallas, Texas, Mar. 14-19, 2010, pp. 3894-3897.
[22] E. Fishler, *et al.*, "Spatial diversity in radars-models and detection performance," *IEEE Trans. on Signal Process.*, vol. 54, pp. 823-838, 2006.

[23] Z. Wang, A. Sinha, P. Willett, and Y. Bar-Shalom, "Angle estimation for two unresolved targets with monopulse radar," *IEEE Transactions on Aerospace and Electronic Systems*, vol. 40, no. 3, pp. 998-1019, Jul. 2004.

[24] Z.-G Shi, *et al.*, "Ambiguity functions of direct chaotic radar employing microwave chaotic colpitts oscillator," *Progress in Electromagnetics Research*, vol. 77, pp. 1-14, 2007

[25] C. Du, J. S. Thompson, and Y. Petillot, "Predicted detection performance of MIMO radar," *IEEE Signal Processing Letters*, vol. 15, pp. 83-86, 2008.

[26] S. C. Surender and R. M. Narayanan, "UWB noise-OFDM netted radar: Physical layer design and analysis," *IEEE Trans. Aerosp. Electron. Syst.*, vol. 47, no. 2, pp. 1380-1400, Apr. 2011.

[27] S. Bhattacharjee, S. Debroy, M. Chatterjee, and K. Kwiat, "Utilizing misleading information for cooperative spectrum sensing in cognitive radio networks," in *Proc. IEEE ICC*, 2013.

[28] Y. Nijsure, *et al.*, "Novel system architecture and waveform design for cognitive radar radio networks," *IEEE Transactions on Vehicular Technology*, vol. 61, no. 8, pp. 3630-3642, Oct. 2012.

[29] S. Sodagari, A. Khawar, T. Clancy, and R. McGwier, "A projection-based approach for radar and telecommunication systems coexistence," in *Proc. IEEE Global Commun. Conf., Anaheim*, CA, Dec. 2012.

[30] Y. Chen, G. Yu, Z. Zhang, H. Chen, and P. Qiu, "On cognitive radio networks with opportunistic power control strategies in fading channels," *IEEE Trans. Wireless Commun.*, vol. 7, no. 7, pp. 2752-2761, Jul. 2008.

[31] D. Grace, J. Thornton, G. Chen, G. White, and T. C. Tozer, "Improving the system capacity of broadband services using multiple high-altitude platforms," *IEEE Transactions on Wireless Communication*, vol. 4, no. 20, pp. 700-709, 2005.

[32] G. M. Djunnic and J. Freidenfelds, "Establishing wireless communications services via high-altitude aeronautical platforms: A concept whose time has come?" *IEEE Commun. Magazine*, vol. 35, no. 9, pp. 128-135, Sep. 1997.

[33] M. K. Simon, *Digital Communication over Fading Channels*, New Jersy: John Wiley and Sons, Ltd., 2005.

[34] G. Ganesan and Y. Li, "Cooperative spectrum sensing in cognitive radio networks," in *Proc. 1st IEEE International Symposium on New Frontiers in Dynamic Spectrum Access Networks*, Nov. 2005, pp. 137-143.

[35] M. Wicks, "Spectrum crowding and cognitive radar," in *Proc. 2nd International Workshop on Cognitive Information Processing*, Elba Island, Italy, Jun. 2010.

[36] A. Mohammed, S. Arnon, D. Grace, M. Mondin, and R. Miura, "Advanced communications techniques and applications for highaltitude platforms," *EURASIP Journal on Wireless Commun. and Networking*, 2008.

[37] J. D. Taylor, *Ultra-Wideband Radar Technology*, Florida: CRC Press, 2000, pp. 133.

[38] S. V. Vaseghi, *Advanced Digital Signal Processing and Noise Reduction*, 3rd ed., UK: John Wilen & Sons, Ltd., 2006.

[39] H. R. Raemer, *Radar System Principles*, London: CRC Press LLC, 1997.

[40] M. Barkat, *Signal Detection and Estimation*, 2nd ed. United States of America: Artech House Radar Library, 2005.

[41] G. Galati, *Advanced Radar Techniques and Systems*, United Kingdom: Peter Peregrinus Ltd., 1993.

[42] D. C. Schleher, *Automatic Detection and Data Processing. Dedham*, MA: Artech House, 1980.

Ashagrie G. Flattie was born Bahir-Dar in September 1977. He received Bachelor degree in Electrical Engineering with Specialization Communication technology from Defense University, DebreZeit, Ethiopia, in 2003 and M.Sc. Degree in electrical and computer engineering from Addis Ababa University, Addis Ababa, Ethiopia, in 2008.

He started his career as a lecturer at Ethiopia Air Force, in 2003 later then he was working in INSA (Information Security Agency). For the last seven years he was working in telecommunication as Mobile Planning and Optimization Manager, Quality and Performance Manager, and Engineering RAN Manager and currently he is working as Engineering Officer at Ethio-Telecom, Addis Ababa, Ethiopia.

Mr. Flattie has published 10 research papers in International Conference. His current research interests include in the field of wireless communication, High altitude platform (HAPs), Satellite communication, Radar, MIMO, Propagation model, Mobile(GSM, CDMA, WCDMA and LTE) planning and optimization, cognitive and Cooperative communication.