On-board the Satellite Interference Detection with Imperfect Signal Cancellation

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***Abstract*— Interference issues have been identified as a threat for satellite communication systems and services, resulting in throughput degradation and revenue loss to the satellite operators. In this context, an on-board spectrum monitoring unit (SMU) can be used to detect interference reliably. Current satellite SMUs are deployed on the ground and the introduction of an in-orbit SMU can bring several benefits, e.g. simplifying the ground based station in multibeam systems. This paper proposes a two-step algorithm for on-board interference detection, exploiting the frame structure of DVB-S2X standard, which employs pilot symbols for data transmission. Assuming that the pilot signal is known at the receiver, it can be removed from the total received signal. Then, an Energy Detection (ED) technique can be applied on the remaining signal in order to decide the presence or absence of interference. The simulation results show that the proposed technique outperforms the conventional ED in low interference-to-signal and noise ratios (ISNRs).**

***Index Terms*—Energy Detector, signal cancellation, interference detection, on-board processing, chi-squared distribution.**

I. Introduction

Interference has been identified as a major threat for satellite communication systems and services having a financial impact on the satellite operators that can run into several million dollars [1]. The situation is likely to become worse over the next years, as new two way services are deployed.

Effectively tackling interference is a complex task to be performed at various levels: interference monitoring; interference detection and isolation; interference classification; interference localisation; and interference mitigation. In this paper, we focus on the detection of interference. A method to detect interference is the use of a so-called spectrum monitoring unit. While current satellite SMUs are deployed on the ground [2]-[3], there are some attempts to design in-orbit tools for this purpose [4]. The introduction of an in-orbit SMU would bring several benefits, e.g. allowing faster reaction to resolve interference before the downlink impairment and simplifying the ground based stations in multi-beam satellites by avoiding equipment replication in multiple earth stations. However, on-board implementation faces some technical challenges which have to be taken into account, with the most important one being the minimization of the complexity/power consumption.

In this paper, we assume that we have a single input-single output scenario (SISO) and as mentioned earlier, we should design a detector with low complexity. The most popular detector, due to its simplicity, is the Energy Detector [5]-[9]. The ED measures the energy of the total received signal and compares it with a properly selected threshold, γ, in order to decide the presence or absence of interference. As we will see in the numerical results, the ED is a good detection scheme, especially for strong interference scenarios. However, when the interfering signal has a power lower than the authorised signal, the reliable detection of the interfering signal becomes difficult, as conventional ED requires accurate knowledge of both the noise and the desired received signal power level on-board the satellite in order to calibrate the appropriate detection thresholds.

To address this issue, we propose a technique for the detection of interference on-board the satellite with the name "ED with signal cancellation". This method is the main contribution of this paper, exploiting the frame structure of the DVB-S2X standard [10], which employs pilot symbols in its transmission and considering how the imperfections of the cancellation affect the detection performance. Furthermore, we derive the detection performance parameters, i.e. the probabilities of false alarm, P_{FA} and detection, P_D, for the cases with and without noise and desired received signal uncertainties (these are termed noise uncertainty and signal power uncertainty, respectively). As shall be shown later, our proposed technique provides better detection performance and needs fewer number of samples than the conventional ED.

The rest of this paper is organized as follows. In Section II, the system model is described. In Section III, the algorithms based on the exploitation of the pilot symbols are presented. Numerical results are depicted in Section IV. Finally, Section V concludes the paper.

Notation: Bold-face letters are used to denote matrices and vectors and the Hermitian of a vector $\mathbf{x}$ is defined as $\mathbf{x}^H$. The chi-squared distribution with q degrees of freedom is denoted χ_q^2.

II. System model

An example of interference imposed on the satellite is depicted in Figure 1. The interfering source which is transmitting towards the operational satellite may be due to operator errors, poor equipment setup, jamming, etc. Based on this, we consider the case where a single antenna is employed on-board the satellite to detect interference, while the desired and interfering earth station (ES) also have one transmit antenna.

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This setup is particularly appropriate for most of the existing satellite payloads and terminal architectures. Then, the detection problem can be formulated as the following binary hypothesis test, which is a base-band symbol sampled model:

$$\mathcal{H}_0 \quad : \mathbf{x}{=}h\mathbf{s}{+}\mathbf{w}, \tag{1}$$

$$\mathcal{H}_1 \quad : \mathbf{x}{=}\mathbf{i}{+}h\mathbf{s}{+}\mathbf{w}, \tag{2}$$

where h denotes the scalar complex channel which we assume that is static for a long period and represents the channel from the feeder link, $\mathbf{s} = [s(1) \ \cdots s(N)]^T$ denotes a $N \times 1$ complex vector, referred to as the signal transmitted by the desired ES with energy $E_s = \mathbf{s}^H\mathbf{s}$, which we assume as a known sequence (i.e. N pilot symbols based on the DVB-S2X standard), $\mathbf{i} = [i(1) \ \cdots i(N)]^T$ denotes a $N \times 1$ Gaussian complex vector, independent of the signal and noise, with zero mean and unknown covariance matrix given by $E\left\{\mathbf{i}\mathbf{i}^H\right\} = \sigma_i^2\mathbf{I}$, referred to as the interference in the receiving antenna of the satellite, $\mathbf{w} = [w(1) \ \cdots w(N)]^T$ denotes a $N \times 1$ complex vector referred to as the additive noise at the receiving satellite antenna, modelled as an independent and identically distributed (i.i.d.) circularly symmetric complex Gaussian (CSCG) vector with zero mean and covariance matrix given by $E\left\{\mathbf{w}\mathbf{w}^H\right\} = \sigma_w^2\mathbf{I}_N$, where $\mathbf{I}_N$ denotes an identity matrix of size N, and $\mathbf{x} = [x(1) \ \cdots x(N)]^T$ denotes a $N \times 1$ complex vector, referred to as the total received signal at the satellite. Note, that the adopted model for the distribution of $\mathbf{i}$ can be considered as a general model, where the vector $\mathbf{i}$ can be the aggregated signal of one or more independent interference sources, which are further independent over time. This model can be considered as a valid one for the performance evaluation of the developed detector, however as shall be shown later, the calculation of the detection threshold is independent from the distribution of the interfering signal(s) and can be applied to any scenario.

As mentioned in the introduction, the ED is a very popular detection technique, however, it usually faces difficulties to detect low values of ISNR, because it requires the knowledge of the noise and signal power to correctly set the threshold, γ. However, the accurate knowledge of the noise and signal power in practice is not available, hence, the phenomenon of the ISNR wall [11] appears, above which the accurate detection of interference cannot be carried out. Furthermore, even if this knowledge is accurate, the conventional ED needs a large number of samples, which inhibits the fast detection of interference, and further increases the energy consumption on-board the satellite, which is a critical factor for any in-orbit processing technique. For all these reasons, here, we propose a method which exploits the knowledge of the pilot symbols of the DVB-S2X standard.

A. *Algorithm: Energy Detector with signal cancellation*

Step 1: Estimate the channel using the pilot symbols.

Step 2: Remove[1] the pilot symbols from the total received signal: $\mathbf{x}' = \mathbf{x} - h\mathbf{s}$.

Step 3: Apply a simple ED

$$T(\mathbf{x}') = \|\mathbf{x}'\|^2 = \sum_{n=0}^{N-1} |x'_n|^2 \begin{array}{l} <\rightarrow \mathcal{H}_0 \\ >\rightarrow \mathcal{H}_1 \end{array}, \tag{3}$$

where $\|\cdot\|$ denotes the standard vector norm.

It should be noted that for this method to be successful, a proper frame synchronisation is necessary for the on-board processing module in the satellite. In this paper, we assume perfect frame synchronization, however the effect of inaccurate frame synchronization on the performance of the proposed detector shall be studied in future works. In the following sections, we consider and compare three methods: i) the conventional ED (CED), ii) the ED with perfect signal cancellation (EDPSC) and iii) the ED with imperfect signal cancellation (EDISC).

[1] Based on the DVB-S2X standard, after the successful frame synchronization, we know exactly the positions of the pilot symbols, which we can extract and save in a buffer. Then, the analysis of the detection of interference is carried out on this pilot signal.

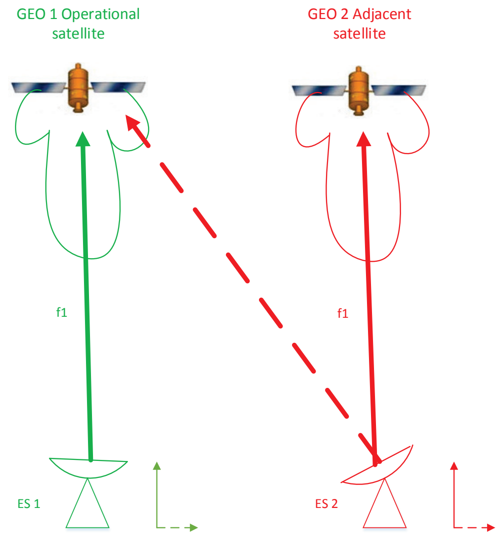

Fig. 1: Interference Scenario for feeder link.

III. Exploitation of Pilot Signals

A. *Conventional ED*

In this case, we apply the ED of (3), directly, in the hypothesis test of (1), (2). Then, the distribution of the test statistic, $T(\mathbf{x})$, follows a non-central chi-square distribution with $2N$ degrees of freedom under both hypotheses, $\mathcal{H}_0$ and $\mathcal{H}_1$, and the P_{FA} and P_D can be expressed in closed form as

$$P_{FA} = Q_N\left(\sqrt{\rho_{\mathcal{H}_0}}, \sqrt{\frac{2\gamma}{\sigma_w^2}}\right), \tag{4}$$

$$P_D = Q_N\left(\sqrt{\rho_{\mathcal{H}_1}}, \sqrt{\frac{2\gamma}{\sigma_i^2 + \sigma_w^2}}\right), \tag{5}$$

where $Q_m(a, b)$ is the generalized Marcum-Q function and the non-centrality parameter, ρ, is given by $\rho_{\mathcal{H}_0} = \frac{2|h|^2 E_s}{\sigma_w^2}$ and $\rho_{\mathcal{H}_1} = \frac{2|h|^2 E_s}{\sigma_w^2 + \sigma_i^2}$, respectively.

However, in practice, the noise and signal power are usually unknown. Then, the P_{FA} and P_D under the condition of noise and signal power uncertainty can be expressed in closed form as

$$P_{FA} = Q_N\left(\sqrt{\frac{2\eta_h|h|^2E_s}{\eta_w\sigma_w^2}}, \sqrt{\frac{2\gamma_{unc}}{\eta_w\sigma_w^2}}\right), \quad (6)$$

$$P_D = Q_N\left(\sqrt{\rho_{\mathcal{H}_1}}, \sqrt{\frac{2\gamma_{unc}}{\sigma_i^2+\sigma_w^2}}\right), \quad (7)$$

where γ_{unc} is the selected threshold under the uncertainty scenario and the uncertainty factor can be defined as $B = 10\log_{10}\eta$, with B to be in dB. Also, the indices h and w represent the channel and noise, respectively.

Using the central limit theorem (CLT), the probability density function (PDF) of the test statistic, $T(\mathbf{x})$, under both hypotheses, H_0 and H_1 can be approximated by a Gaussian distribution. Then, based on some simple mathematical calculations, the number of required samples to achieve a given pair of target probabilities (P_{FA}, P_D) is given by $N = \left(\frac{A-B}{\sigma_i^2}\right)^2$, where $A = Q^{-1}(P_{FA})\sqrt{\sigma_w^4 + 2\sigma_w^2 P_s}$ and $B = Q^{-1}(P_D)\sqrt{(\sigma_w^2+\sigma_i^2)^2 + 2(\sigma_w^2+\sigma_i^2)P_s}$. Finally, if there is noise and signal power uncertainty, the number of samples is given by $N_{unc} = \left(\frac{C-D}{\sigma_i^2+\sigma_w^2+E_s-\eta_w\sigma_w^2-\eta_h E_s}\right)$, where $C = Q^{-1}(P_{FA})\sqrt{(\eta_w\sigma_w^2) + 2\eta_w\sigma_w^2\eta_h P_s}$ and $D = Q^{-1}(P_D)\sqrt{(\sigma_w^2+\sigma_i^2)^2 + 2(\sigma_w^2+\sigma_i^2)P_s}$, where P_s represents the power of the desired transmitted signal, $h\mathbf{s}$.

B. ED with perfect signal cancellation

In this case, we assume that we have perfect knowledge of the channel, h, and signal, $\mathbf{s}$, (pilot symbols). This is presented merely as a benchmark, otherwise in reality, perfect cancellation is not possible. If we subtract the DVB-S2X signal, $h\mathbf{s}$, from the received signal, $\mathbf{x}$, the hypothesis test of (1), (2) becomes

$$\begin{array}{llll} \mathcal{H}_0 & : \mathbf{x} = \mathbf{w} & \text{or} & \mathbf{x} \sim \mathcal{CN}\left(\mathbf{0}, \sigma_w^2\mathbf{I}_N\right), \\ \mathcal{H}_1 & : \mathbf{x} = \mathbf{i} + \mathbf{w} & \text{or} & \mathbf{x} \sim \mathcal{CN}\left(\mathbf{0}, \left(\sigma_i^2+\sigma_w^2\right)\mathbf{I}_N\right). \end{array} \quad (8)$$

Then, the ED can be applied as has been shown in (3). This model has been studied a lot in the literature [12], thus, the P_{FA} and P_D for this ED can be expressed in closed form as $P_{FA} = \frac{\Gamma\left(N, \frac{\gamma}{\sigma_w^2}\right)}{\Gamma(N)}$ and $P_D = \frac{\Gamma\left(N, \frac{\gamma}{\sigma_w^2+\sigma_i^2}\right)}{\Gamma(N)}$, where $\Gamma(k)$ is the gamma function evaluated at k and $\Gamma(k,\theta)$ is the upper incomplete gamma function. Under the noise uncertainty case, the corresponding P_{FA} and P_D are given by $P_{FA} = \frac{\Gamma\left(N, \frac{\gamma_{unc}}{\eta_w\sigma_w^2}\right)}{\Gamma(N)}$ and $P_D = \frac{\Gamma\left(N, \frac{\gamma_{unc}}{\sigma_w^2+\sigma_i^2}\right)}{\Gamma(N)}$.

C. ED with imperfect signal cancellation

However, in practice, it is hard to have perfect knowledge of the channel, which should be estimated. In this part, we evaluate how the imperfect channel estimation affects the interference detection performance. First, we focus on the hypothesis $\mathcal{H}_0$, where interference is absent and subsequently, to the hypothesis $\mathcal{H}_1$, where interference is present.

1) Hypothesis $\mathcal{H}_0$: The channel can be estimated by using the least square estimator, i.e. $\hat{h} = \left(\mathbf{s}^H\mathbf{s}\right)^{-1}\mathbf{s}^H\mathbf{x}$ and then, the estimated channel, $\hat{h}$, can be modelled as

$$\hat{h} = h + \varepsilon, \quad (9)$$

where the channel estimation error, ε, is given by $\varepsilon = \left(\mathbf{s}^H\mathbf{s}\right)^{-1}\mathbf{s}^H\mathbf{w}$ with covariance $E\{\varepsilon\varepsilon^*\} = \sigma_w^2\left(\mathbf{s}^H\mathbf{s}\right)^{-1}$.

Therefore, if we remove the DVB-S2X pilot signal from the received signal of (1), taking into account the imperfect channel estimation of (9), the hypothesis test of (1) becomes

$$\mathcal{H}_0 : \mathbf{x}' = \mathbf{w} - \varepsilon\mathbf{s}, \quad (10)$$

with covariance matrix $R_0 = E\left\{\mathbf{x}'\mathbf{x}'^H\right\} = \sigma_w^2\mathbf{I} - \sigma_w^2\left(\mathbf{s}^H\mathbf{s}\right)^{-1}\mathbf{s}\mathbf{s}^H$. Since the covariance matrix R_0 is not diagonalized, it can be seen that the elements of the vector $\mathbf{x}'$, $\{x'_n\}_{n=1}^N$ are correlated.

2) Hypothesis $\mathcal{H}_1$: Following the same procedure as under the hypothesis $\mathcal{H}_0$, the hypothesis test of (2) becomes

$$\mathcal{H}_1 : \ \mathbf{x}' = \mathbf{i} + \mathbf{w} - \varepsilon'\mathbf{s}, \quad (11)$$

where the channel estimation error ε', under $\mathcal{H}_1$, is given by $\varepsilon' = \left(\mathbf{s}^H\mathbf{s}\right)^{-1}\mathbf{s}^H(\mathbf{w}+\mathbf{i})$ with covariance $E\left\{\varepsilon'\varepsilon'^H\right\} = \left(\sigma_w^2+\sigma_i^2\right)\left(\mathbf{s}^H\mathbf{s}\right)^{-1}$. Furthermore, the covariance matrix of $\mathbf{x}'$ is given by $R_1 = E\left\{\mathbf{x}'\mathbf{x}'^H\right\} = \left(\sigma_w^2+\sigma_i^2\right)\mathbf{I} - \left(\sigma_w^2+\sigma_i^2\right)\left(\mathbf{s}^H\mathbf{s}\right)^{-1}\mathbf{s}\mathbf{s}^H$. Also here, it can be seen that the elements of the vector $\mathbf{x}'$, $\{x'_n\}_{n=1}^N$ are correlated.

Again, the ED can be applied in (10) and (11). To evaluate the ED, we should know what is the distribution of the test statistic $T(\mathbf{x}')$ under both hypotheses, H_0 and H_1, namely, what is the distribution of N correlated chi-squared or gamma random variables, each of which has 2 degrees of freedom.

Following the approach presented in [13], the distribution of the test statistic, $T(\mathbf{x}')$, can be approximated by the following model

$$\mathcal{H}_0 \quad : T(\mathbf{x}') \sim c_{\mathcal{H}_0}x^2_{f_{\mathcal{H}_0}}, \quad (12)$$

$$\mathcal{H}_1 \quad : T(\mathbf{x}') \sim c_{\mathcal{H}_1}x^2_{f_{\mathcal{H}_1}}, \quad (13)$$

where

$$c = \frac{V(T(\mathbf{x}'))}{2E(T(\mathbf{x}'))}, f = \frac{2E(T(\mathbf{x}'))^2}{V(T(\mathbf{x}'))}. \quad (14)$$

Therefore, the knowledge of the mean, $E(T(\mathbf{x}'))$ and variance, $V(T(\mathbf{x}'))$, of the test statistic is required. This knowledge can be acquired through the moment generatic function (MGF) of the test statistic, as follows [14]

$$M_{T(\mathbf{x}')}(s)_{\mathcal{H}_0} = \prod_{n=1}^{N}\left(1 - s\left(\sigma_w^2 - \frac{\sigma_w^2}{E_s}\lambda_n\right)\right)^{-1}, \quad (15)$$

$$M_{T(\mathbf{x}')}(s)_{\mathcal{H}_1} = \prod_{n=1}^{N}\left(1 - s\left(\sigma_i^2 + \sigma_w^2 - \frac{\sigma_w^2+\sigma_i^2}{E_s}\lambda_n\right)\right)^{-1}, \quad (16)$$

where s in (15), (16) referred to the Laplace transform and λ_n is the n-th eigenvalue of the matrix $\mathbf{s}\mathbf{s}^H$ of the covariance matrix R_0 and R_1, respectively. Then, using the first and second derivative of the MGF, the mean and variance of the test statistic can be easily derived and the P_{FA} and P_D for the ED with imperfect signal cancellation can be expressed as

$$P_{FA} = \frac{\Gamma\left(\frac{f_{\mathcal{H}_0}}{2}, \frac{\gamma \sum_{n=1}^{N}\left(\sigma_w^2 - \frac{\sigma_w^2}{E_s}\lambda_n\right)}{\sum_{n=1}^{N}\left(\sigma_w^2 - \frac{\sigma_w^2}{E_s}\lambda_n\right)^2}\right)}{\Gamma\left(\frac{f_{\mathcal{H}_0}}{2}\right)}, \tag{17}$$

$$P_D = \frac{\Gamma\left(\frac{f_{\mathcal{H}_1}}{2}, \frac{\gamma \sum_{n=1}^{N}\left(\sigma_i^2 + \sigma_w^2 - \frac{\sigma_w^2+\sigma_i^2}{E_s}\lambda_n\right)}{\sum_{n=1}^{N}\left(\sigma_i^2 + \sigma_w^2 - \frac{\sigma_w^2+\sigma_i^2}{E_s}\lambda_n\right)^2}\right)}{\Gamma\left(\frac{f_{\mathcal{H}_1}}{2}\right)}. \tag{18}$$

However, because the transmitted signal, s, is a fixed known sequence, which implies rank 1 signal, the first eigenvalue is $\lambda_1 = \mathbf{s}^H\mathbf{s} = E_s$ and the rest are $\lambda_1 = \lambda_2 = ... = \lambda_N = 0$. Hence, (17) and (18) can be simplified into the following model

$$P_{FA} = \frac{\Gamma\left(N-1, \frac{\gamma}{\sigma_w^2}\right)}{\Gamma(N-1)}, \tag{19}$$

$$P_D = \frac{\Gamma\left(N-1, \frac{\gamma}{\sigma_w^2+\sigma_i^2}\right)}{\Gamma(N-1)}, \tag{20}$$

which looks like an ED with one less degree of freedom. The corresponding equations for the noise uncertainty case are given by

$$P_{FA} = \frac{\Gamma\left(N-1, \frac{\gamma_{unc}}{\eta_w \sigma_w^2}\right)}{\Gamma(N-1)}, \tag{21}$$

$$P_D = \frac{\Gamma\left(N-1, \frac{\gamma_{unc}}{\sigma_w^2+\sigma_i^2}\right)}{\Gamma(N-1)}. \tag{22}$$

Therefore, we can notice that the proposed ED with signal cancellation technique is affected only by the noise uncertainty compared to the classical ED which has to take into account the noise and signal power uncertainty.

As we showed earlier, the source of the correlation is the error of the imperfect channel estimation. Thus, when the number of samples is large, the channel estimation is almost accurate and the correlation between the samples is negligible. The central limit theorem (CLT) can be applied and the test statistic $T(\mathbf{x}')$ under both hypotheses, $\mathcal{H}_1$ and $\mathcal{H}_0$ can be approximated by a Gaussian distribution. Then, based on some simple mathematical calculations, the number of required samples to achieve a given pair of target probabilities (P_{FA}, P_D) is given by $N = \left(\frac{Q^{-1}(P_{FA})\sqrt{\sigma_w^4} - Q^{-1}(P_D)\sqrt{(\sigma_w^2+\sigma_i^2)^2}}{\sigma_i^2}\right)^2 + 1$. Finally, if there is noise uncertainty, the number of samples is given by $N_{unc} = \left(\frac{Q^{-1}(P_{FA})\sqrt{(\eta\sigma_w^2)} - Q^{-1}(P_D)\sqrt{(\sigma_w^2+\sigma_i^2)^2}}{\sigma_i^2+\sigma_w^2-\eta\sigma_w^2}\right)^2 + 1.$

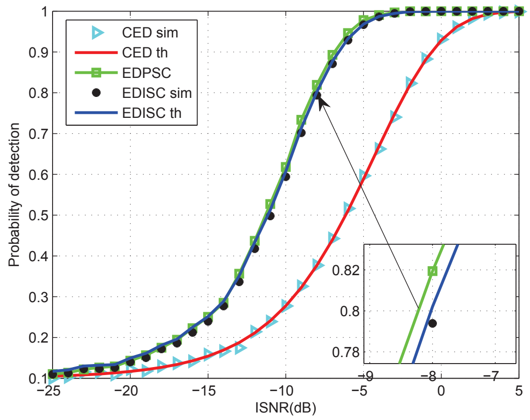

Fig. 2: Probability of interference detection versus the ISNR comparing three different techniques for $N = 10$, $E_s = 0$ dB and $\sigma_w^2 = -7$ dB.

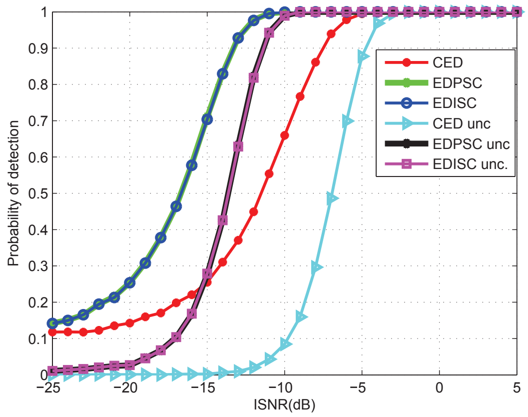

Fig. 3: Probability of interference detection versus the ISNR for $N = 100$, $E_s = 0$ dB and $\sigma_w^2 = -7$ dB, with uncertainty 0.5 dB for both, noise and desired received signal.

IV. Numerical Results

Here, we present simulation results to illustrate the detection performance of the proposed interference detection technique. Throughout this section, we assume that the transmitted useful signal is fixed and known. $10,000$ Monte Carlo simulations are carried out and the detection threshold is set such that the probability of false alarm is $P_{FA} = 0.1$. Furthermore, the ISNR ranges from -25 to 5 dB.

Figures 2 and 3 show the probability of interference detection versus the ISNR comparing the aforementioned techniques: i) CED, ii) EDPSC and iii) EDISC, where we can notice that the proposed ED with signal cancellation method provides much better interference detection performance than the conventional ED. Furthermore, we can see that when the number of samples, N, increases from 10 to 100 the CED provides $P_D \approx 1$ for ISNR$= -5$ dB. However, this ISNR can be detected by the EDISC by using only 10 samples, thus, less number of samples is required with the proposed algorithm. Also, it can be noted,

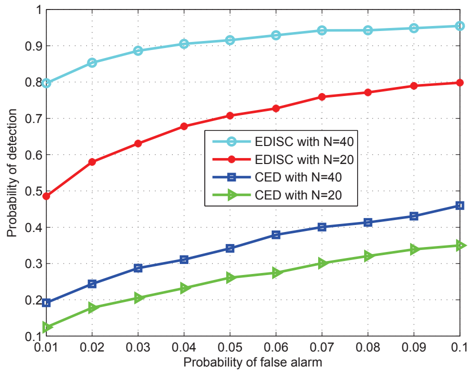

Fig. 4: ROC curves for classical ED and ED with imperfect cancellation when ISNR$= -10$ dB, $E_s = 0$ dB and $\sigma_w^2 = -7$ dB.

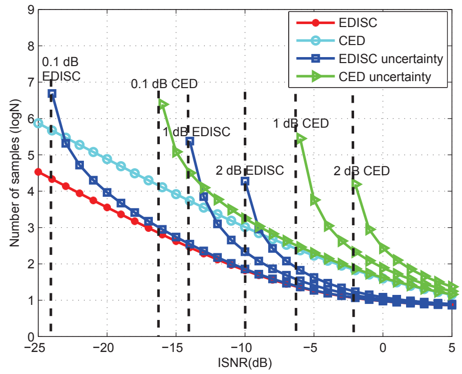

Fig. 5: Number of samples in log versus the ISNR in dB for signal and noise with and without uncertainty for the case of the CED and EDISC.

that the EDISC approaches the detection performance of the EDPSC when the number of samples increases. The reason is that using more samples, the channel estimation is more accurate, so the effect of the channel estimation error can be neglected. Moreover, Figure 2 shows that the simulation results validate the accuracy of the derived expressions. Finally, Figure 3 depicts the effect of the noise and channel uncertainty (0.5 dB for both cases). We can see that the detection performance of our proposed technique decreases because of the uncertainty. Something that we can also notice here is that the effect of the uncertainty in the performance of the CED is larger than our proposed technique. The reason is that our technique after the cancellation depends only on the noise uncertainty, but the classical ED depends on both, noise and signal power uncertainty.

Figure 4 presents the receiver operating characteristic (ROC) curves of the CED and EDISC for $N = 20$, $N = 40$ and ISNR$= -10$ dB. It is again observed that the EDISC performs much better than the CED. Furthermore, Figure 5 shows the required number of samples that we need in order to detect interference for a fixed $P_D = 0.99$ and $P_{FA} = 0.1$ for the case of the CED and EDISC. Also, we can see how the sample complexity N varies for the energy detector as the ISNR approaches the ISNR wall. Therefore, when there is 2 dB uncertainty, the CED cannot robustly detect interference for ISNR less than -2 dB, however, the ISNR wall for the EDISC is appeared in -10 dB, which is much less than CED. Finally, we can see that the targeting ISNR can be obtained by using less number of samples if we use the proposed signal cancellation method.

V. Conclusion

In this paper, we presented an interference scenario on the uplink of a of a satellite earth station and discussed the benefits of introducing an on-board SMU for the detection of interference. The SMU should be able to implement and calibrate a number of detection algorithms to identify any interference on carriers. A two-step interference detection algorithm to be used on-board the satellite was proposed by exploiting the pilot symbols of the DVB-S2X frame, where the pilot signal is removed from the total received signal and then a simple ED is applied in order to decide for the absence or presence of interference. Furthermore, we derived the closed form expressions of the probability of false alarm and detection for this proposed interference detection scheme. Moreover, we showed that the EDISC technique provides much better detection performance than the CED and that it is less sensitive to the variance uncertainty, because only information of the noise is required, not the level of our own signal which might not be available on-board. Finally, the simulation results validated the accuracy of the derived expressions.

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