IWNEST PUBLISHER

Journal of Industrial Engineering Research

(ISSN: 2077-4559)

Journal home page: http://www.iwnest.com/AACE/

Adaptive Time-Quantized pseudorandom Sampling scheme for Green Communication

[1]A. Raja Thilagam and [2]Dr. R. Suresh Babu

[1]*Anna University, M.E Communication and Networking,Kamaraj college of engineering and technology,virudhunagar,Tamilnadu,India*
[2]Associate professor, *Kamaraj College of Engineering and Technology,Virudhunagar,Tamilnadu,India*

ARTICLE INFO

Article history:
Received 22 February 2015
Accepted 20 March 2015

Keywords:
Baseband stage, green communication, multistandard receiver, Adaptive time-quantized pseudorandom sampling(ATQ-PRS).

ABSTRACT

In this paper, the propose method uses adaptive time- quantized pseudorandom sampling (ATQ-PRS) as a power-saving solution compared with conventional uniform sampling. The adaptive time-quantized pseudorandom sampling (ATQ-PRS) is an advantageous processing, which is a new sampling design in which sampling regions, defined as "units", are selected based on values of the variables of interest. The method is to improve the power efficiency of wireless sensor network .So it is used for SDR multi standard receiver design. The ATQ-PRS allows aliases attenuation leading to a relaxed receiver baseband stage. Adaptive Time Quantized pseudo Random Sampling technique in the multi stand radio receiver for the baseband power consumption Due to its ability to reduce replicas' power levels, ATQ-PRS reduces the design constraints on receiver components. Applied on the baseband stage of a multi standard radio receiver, ATQ-PRS allows decreasing the anti aliasing filter order, as well as reducing the sampling frequency. This feature leads to saving up to 40% of baseband power consumption.

To Cite This Article: A. Raja Thilagam and Dr. R. Suresh Babu., Adaptive Time-Quantized pseudorandom Sampling scheme for Green Communication. **J. Ind. Eng. Res.,** ***1(2),*** *22-28, 2015*

INTRODUCTION

Power crisis is one of the major problems faced by our country. Saving of power means, it is an indirect way of power producing. In the interest of saving power while preserving the flexibility of terminals to connect to different standards of communication, solutions for green communication have emerged. Adaptive modulation and coding [1], intelligent allocation of spectrum in cognitive radio [2], and other concepts are proposed to optimize the required power [3]. Thus, radio receivers have to be programmable with low power consumption. In this scope, the authors propose to substitute the uniform sampling (US) with random sampling (RS). Due to its alias reduction feature, RS promises to reduce constraints on receiver components [4] and therefore their power consumption. Previous work demonstrates the ability of time-quantized RS (TQ-RS) of reducing constraints on receiver component [5].In this brief, the proposed work considers the implementation version of TQ-RS known as time-quantized pseudorandom sampling (TQ-PRS). This sampling technique is applied on the baseband stage multistandard receiver. Simulations present a TQ PRS ability of reducing alias, whereas power consumption estimation proves a gain of the baseband stage power consumption. In this scope, the authors propose to substitute the uniform sampling (US) with random sampling (RS). Due to its alias reduction feature, RS promises to reduce constraints on receiver components [4] and therefore their power consumption. Previous work demonstrates the ability of time-quantized RS (TQ-RS) of reducing constraints on receiver component [5].In this brief, the proposed work considers the implementation version of TQ-RS known as time-quantized pseudorandom sampling (TQ-PRS). This sampling technique is applied on the baseband stage multistandard receiver. Simulations present a TQ PRS ability of reducing alias, whereas power consumption estimation proves a gain of the baseband stage power.

II. *Adaptive Time-Quantized Pseudorandomly Sampled Signals In Sdr Multistandard Receiver:*

In this section, we present a review of random sampling and ATQ-PRS schemes which are alias-free sampling and alias attenuation sampling, respectively. The objective is to apply ATQ-PRS in an SDR multistandard receiver to take advantage of ATQ-PRS alias attenuation

Corresponding Author: A. Raja Thilagam, Anna University, M.E Communication and Networking,Kamaraj college of engineering and technology,virudhunagar,Tamilnadu,India

Journal of Industrial Engineering Research, 1(2) March 2015, Pages: 22-28

A.Random Sampling versus Time-Quantized Pseudorandom Sampling:

The random sampling process converts a continuous analog bandpass signal x(t), into its discret $x_s(t)$ representation, as given by (1).

$$x_s(t) = \sum_{k=-\infty}^{+\infty} x\,(t_{k)\,\delta\,(}t - t_{k)} \quad (1)$$

A mean sampling period *T*rs = 1/*f*rs is considered. It is equal to the mean of all instantaneous periods *tk* − *tk*−1, *k* ∈ Z. RS processing ensures reducing the alias if the sampling instants sequence *{tk}* is a punctually stationary one [4]. For implementation purposes, a quantization of the timing axis has to be done. Thus, aTQ-RS is introduced as an implementation variant of RS. The main difficulty of implementing TQ-RS is the use of a totally random number that selects the quantized RS instant. Because of the high cost of totally random number generators, a pseudorandom feature is preferred for an implementation solution of the RS. Then, the most suitable configuration for implementing RS is the TQ-PRS. In this case, a sequence of different values selects the quantized sampling instant with in cyclic periodicity. The quantization is defined by a quantization step Δ = *T*rs/*qT* , where *qT* is the time-quantization factor.If TQ-RS or TQ-PRS scheme is considered, the random sampling is no more alias-free. Therefore, instead of alias-free sampling, the TQ-PRS alias attenuation is considered. This attenuation depends on the over sampling ratio (OSR) which is the ratio of the mean sampling frequency to the Nyquist frequency. The TQ-PRS alias attenuation, between 12 and 24 dB for 10-to-180 OSR range.

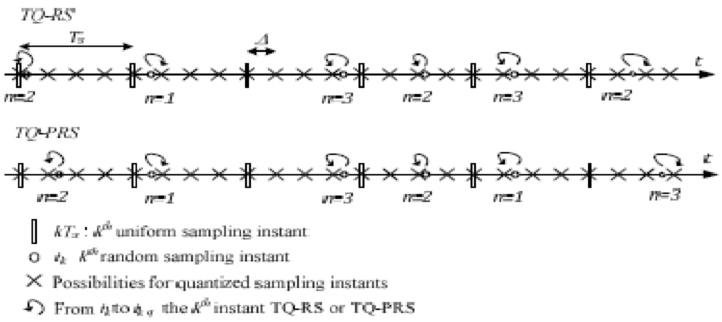

Fig.1. TQ-RS scheme and TQ-PRS scheme description for $q_T = 4$.

B. ATQ-PRS-based SDR Multistandard Receiver:

To reach SDR multistandard receiver that supports E-GSM/UMTS/ IEEE802.11a/b/g, Brandolini *et. al.* proposed RF design requirements for hybrid homodyne/low-IF receiver architecture [7]. This paper proposes to take advantage of ATQPRS alias attenuation in the SDR multistandard receiver. The design and circuit of the ATQ-PRS scheme, the pseudorandom signal sampler (PSS), was presented in [2]. In fact, ATQ-PRS can relax design constraints on baseband stage circuits (AAF, AGC, ADC) [2]. As shown in Fig. 2, the ATQ-PRS-based receiver uses a common radio frequency (RF) front-end for multi standard RF processing. The signal is first received by a multiband antenna and processed by an adequate RF filter selected through an RF switch. Then, the filtered signal is fed to a multiband low-noise amplifier (LNA) and finally down converted to baseband by quadrature mixers.

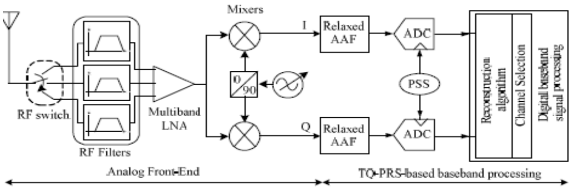

Fig. 2. TQ-PRS-based SDR multistandard receiver architecture.

At analog baseband, the AAF is required to sidestep aliases due to sampling. The ADC has to satisfy constraints in terms of sampling frequency and dynamic range for the chosen standards. In addition, the AGC circuit is generally used to reduce the ADC dynamic range. The ATQ-PRS-based SDR multi standard receiver allows the designers to take advantage of alias attenuation to relax constraints on the ADC or AAF and to avoid AGC use. The ADC is driven by the PSS [2].Then, the digital baseband signal processing starts with a reconstruction algorithm to convert non-uniform samples to uniform samples. The cubic spline reconstruction algorithm offers the best results in terms of dynamic range and complexity [8]. In this paper, we focus on the ATQ-PRS scheme to relax the baseband design of the SDR multi standard receiver. The design results are presented in table I.

The AAF order decreases from 4 to 3 for US and ATQ-PRS, respectively. The ADC consumes less dynamic power with ATQ-PRS than US if we decrease the mean sampling frequency. The proposed design uses a non-programmable 3rd order filter. Thus, the AAF is less complex and consumes lower power than the programmable AAF in [7]. Also, using a nonprogrammable filter does not require an AGC because all the E-GSM interferers and blockers are not filtered. Therefore, the ADC has to process the required dynamic range without the use of AGC. The ADC is low-power consumer, needs a resolution, of 16 bits and samples at a sampling frequency equal to 124 MHz [9]. To validate the obtained advantages of ATQ-PRS-based SDR multi standard receiver, simulations and test setup results are mandatory.

III. *Presentation And Study Of The Atq-Prs:*

The RS technique considers non uniformly time-spaced sampling instants. Such a signal processing promises reducing signal alias while sampling.

A. ATQ-PRS Spectrum:

The ATQ-PRS sampling is first introduced by Bilinskis and Mikelsons [4]. This introduction limited the ATQ-PRS as a way of controlling the randomness of ATQ-RS without demonstrating its reducing alias feature. A MATLAB simulation of Adaptive time-quantize pseudo randomly sampled sine-wave signal is achieved. The oversampling ratio (OSR) is equal to 16 with a quantization factor equal to 8. A sequence of $(qT - 1)$ different values of instantaneous periods are considered. randomly sampled sine-wave signal is achieved. randomly sampled sine-wave signal is achieved. The oversampling ratio (OSR) is equal to 16 with a quantization factor equal to 8. A sequence of $(qT - 1)$ different values of instantaneous periods are considered. The obtained spectrum in Fig. 2 shows the ATQ-PRS effect compared with the US. It can be noticed from Fig. 2 that replicas located around }kfrs, $k \in$ Z are reduced all over the spectrum in ATQ-PRS, whereas spurious replicas appear in each [($k - 1$)$f$rs, kfrs] ,$k \in$ Z. The spurious power level is hugely lower than the signal power level. Every interval contains $(qT - 2)$ pairs of spurious replicas, which appear at $(k - 1)f$rs + lfrs/$(qT - 1)$, $l \in$[[1, $qT - 2$]]. These replicas result from the repetition involved in TQ-PRS signal processing. However, to ensure a good signal-to-noise ratio (SNR), spurious replicas have to be out of the signal bandwidth B. Such condition results in

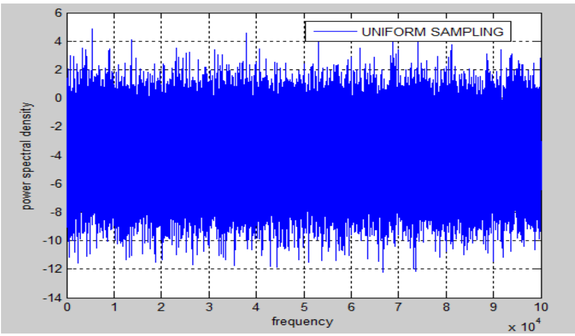

Fig. 3: Simulated spectrum of uniform sampling.

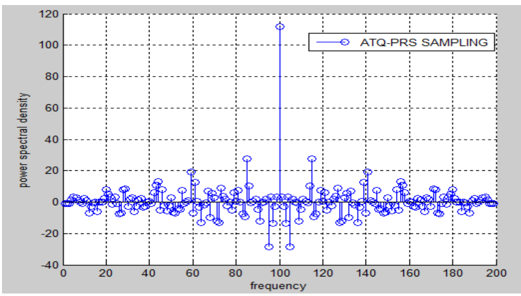

Fig. 4: simulated spectrum of ATQ-PRS sampling.

rs/$(qT - 1) > 2B \Longleftrightarrow OSR \geq qT$. (2)

B. ATQ-PRS Alias Attenuation:

The ATQ-PRS alias attenuation feature can be measured if the signal's power level Psig and replica's power level are compared. The ATQ-PRS alias attenuation noted AttATQ−PRS iscomputed according to the following [6]:

AttATQ−PRS|dB= Psig|dB-− Prep|dBm (3)

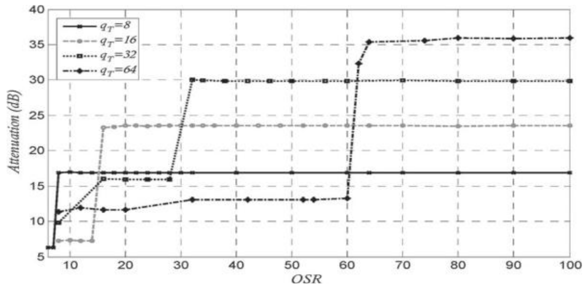

Fig. 5: Measured *AttATQ−PRS|db* according to OSR and ***qT*** values.

Where PRS-pseudo random samping, Att-attenation To measure ATQ-PRS alias attenuation, simulations have been made while varying the mean sampling frequency *f*rs; therefore, varying the OSR and considering a different quantization factor qT . The sine-wave input signal is sampled regarding the TQ-PRS technique. The attenuation results are presentedin Fig. 3 versus the OSR and qT . The condition in (2) is satisfied for all the simulated cases. In addition, the attenuation depends essentially on the quantization factor qT . The attenuation AttATQ−PRS|dB increases with the value of qT and has a horizontal asymptote equal to 20 $log10(qT)$. The power of the replica is distributed on the $(qT-2)$ spurious pairs. When the number of replicas increases, the power level of the replicas decreases as presented in Table I.

Table 1:

q_T	8	16	32	64
Att_{TQ-PRS} (dB)	16.7	23.5	29.8	35.9

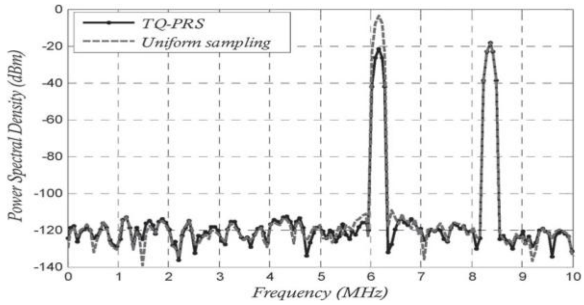

Fig. 6: Attenuated blocker within signal band after ATQ-PRS sampling.

Due to alias reduction, any blocker that would be overlapped on the signal band after sampling is attenuated. For example, considering a blocker at *f*rs − 3*f*in/4, a simulation of the sampling step at the frequency *f*rs = 132.8 MHz of IEEE 802.11a signal at the frequency *f*in = 8.3 MHz leads to have a blocker's replica within the band at the frequency 3*f*in/4. Following the radio receiver front-end stage with 43-dB analog gain, the signal and blocker power levels are at −19 and −4 dBm, respectively [5]. After ATQ-PRS signal processing, samples are pseudo randomly spaced. To conserve the conventional digital signal processing, a reconstruction step is needed after the ATQ-PRS sampling step. The reconstruction goal is to ensure a constant time period between two successive samples The chosen reconstruction process is the spline cubic interpolation [7]. The output of spline cubic reconstruction after ATQ-PRS simulation with a quantization factor $qT = 8$ is given by Fig. 4.

The measured attenuation of 16 dB confirms the AttATQ−PRS value given in Table I. In addition, the reconstruction step ensures reducing the noise at the level of the US one. Furthermore, the attenuation of blockers after sampling leads to decrease constraints on radio receiver components, particularly on the baseband stage.

IV. *Interests Behind Using Atq-Prs On:*
Baseband Stage Circuits:

In this brief, the authors propose to study the impact of using ATQ-PRS in the multistandard baseband stage. The aim of this brief is to show the relaxed constraints that could be introduced to baseband stage components if ATQ-PRS is achieved.

Journal of Industrial Engineering Research, 1(2) March 2015, Pages: 22-28

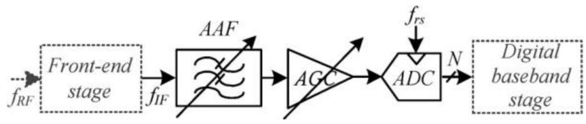

Fig. 7: Mixed baseband stage architecture.

TABLE II: Base b and Stage Configuration Accordingto Adc Characteristics.

	Standard	f_{rs} (MHz)	Provided DR_{ADC} (dB)	Power consumption (mW)	Baseband stage configuration
ADC 1 [9]	GSM	26	82	1.44	AGC use for all standards
	UMTS	208	Na	3.4	
	802.11g	400	52	7	
ADC 2 [10]	GSM	26	88	2.9	AGC use only for GSM
	UMTS	61.44	79	7.4	
	802.11a	240	67	20.5	
ADC 3 [11]	GSM	32	104	18	Without AGC
	UMTS	64	92	23	
	802.11a	160	68	39	

A. Multistandard Baseband Stage:

The analog baseband stage in multistandard receivers has to perform the analog signal processing and digitization before channel selection. The considered radio receiver supports the Global System for Mobile Communications (GSM), the Universal Mobile Telecommunications System (UMTS) and IEEE 802.11a standards. The signal is received by the antenna at the frequency *f*RF and processed within the front-end stage. A homodyne/low-intermediate frequency (IF) receiver is considered [5]. The front-end stage ensures the downconversion of the UMTS and the IEEE 802.11a signals to the baseband. To avoid the flicker noise problem, the GSM signal is downconverted to a low IF *f*IF equal to 100 kHz. Therefore, the signal channel denoted *B* will be equal to 200 kHz, 1.92 MHz, and 8.3 MHz for GSM, UMTS, and IEEE 802.11a, respectively. To ensure the multistandard feature of the mixed baseband stage, all components have to be able to process the signal of different standards and satisfy their specifications. The AAF and the automatic gain control (AGC) have to be programmable in order to attenuate the blockers that could be overlapped over the signal while sampling and to ensure the required amplification of the signal, respectively [8]. The multistandard ADC has to satisfy the standards specifications, particularly in terms of dynamic range and signal bandwidth. A block diagram of the multistandard receiver is given by Fig. 5.

The dynamic range*DR*ADC, which is given by (4), considers the receiver sensitivity *S*min, the maximal input power level *S*max, and the required output SNR *SNR*out as $DR_{ADC} = S_{max} - S_{min} + SNR_{out}$. (4)

The required dynamic range is equal to 96, 73.8, and 61.8 dB for the GSM, the UMTS, and the IEEE 802.11a, respectively. Baseband stage configuration is presented in Table II according to the characteristics of state-of-the-art multistandard ADCs [9]–[11].

Three configurations of the baseband stage are possible regarding the performances of the chosen multistandard ADCs. In fact, if the ADC performances in terms of dynamic range do not ensure the required values imposed by communication standards, an AGC has to be used for power compensation.

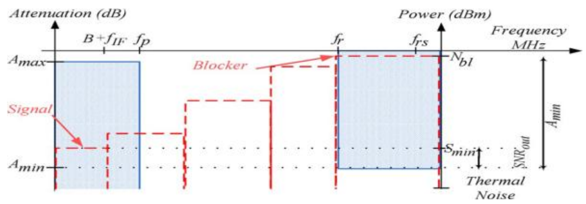

Fig. 8:

B. Impact of ATQ-PRS Use on AAF Order:

The AAF must precede the ADC. The AAF has to remove all spectrum parts that could be aliased over the desired band. Its design depends on the blocker level to be attenuated, *Nbl*, the receiver sensitivity, *S*min, and the output SNR, *SNR* out. The AAF design defines the maximum allowed attenuation within the signal band, i.e., *A*max, and the minimum attenuation, i.e.,

*A*min, which is required to reduce the blocker's level. AAF design is explained by Fig. 6. The AAF design considers the cutoff frequency *fp* and the rejection frequency *fr*. The cutoff frequency is at least equal to *B* + *f*IF. Usually, a margin of 30% has to be considered to take into account the variations of resistors and capacitors of the AAF circuit. As the proposed receiver architecture is a homodyne/low-IF architecture, the considered *fp* values are 0.26, 2.49, and 10.79 MHz for GSM, UMTS, and IEEE 802.11a, respectively. The rejection frequency is equal to *f*rs − *B*. The effect of the receiver front-end stage circuits, such as low-noise amplifiers and mixers, is neglected since their gain and noise are equally added to test signal, interferers, in-band blockers, and out-of-band blockers. In such condition, the *A*min can be written as presented by (5) with a margin of 3 dB, *M*AAF. In the case of using ATQ-PRS, AttATQ−PRS reduces the required *A*min as presented by

*A*min =*Nbl* − *S*min + *SNR*out +*M*AAF (5)

*A*minATQ−PRS =*A*min − AttATQ−PRS. (6)

Where In the case of ATQ-PRS, *A*min is reduced by the TQ-PRS alias attenuation AttATQ−PRS, as in (6), leading to decreased AAF order.

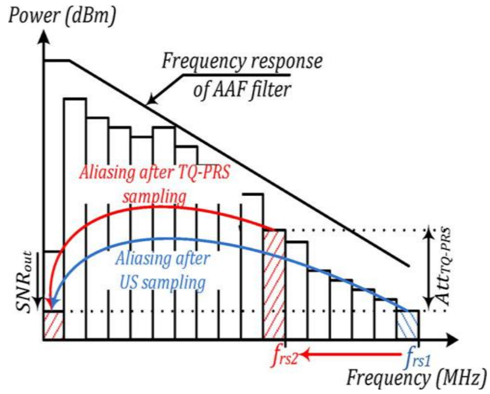

Fig. 9: ATQ-PRS effect on reducing the sampling frequency.

Conclusion:

The work presented in this brief has illustrated the abilityof ATQ-PRS to reduce alias leading to an attenuated blocker level after the sampling step. This feature can be exploited for decreasing either AAF order or sampling frequency. The design of a multistandard baseband stage proves either a reduction of one pole of AAF or a reduction of up to five times the sampling frequency. In addition, in terms of multistandard baseband stage power consumption, the ATQ-PRS with reducing sampling frequency can save up to 30% compared with the US. Future works will focus on including digital part of baseband stage (digital signal processing) and proving the power-saving estimation while using the ATQ-PRS scheme.

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