Determination of SDR-Sliding Correlator Channel Sounder Parameters for Ionospheric Channel Probing

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Abstract

To obtained the ionosphere channel characteristic comprehensively, the design of a sliding correlator channel sounder based on Software Defined Radio (SDR) should be taken carefully. This paper explained the algorithm to determine the parameter values of sliding correlator channel sounder and SDR configuration for observing the ionosphere channel with consideration to the specification of SDR device and the ITU ionospheric channel characteristic recommendation. The capability of the designed channel sounder is specified to determine the parameter values of the designed systems. A result from example implementation for low latitude ionosphere region shows the obtained temporal resolution are smaller than the theoretical capability and could be accepted.

1 Introduction

To obtained the information of wireless channel characteristic in comprehensively, the determination of optimum channel sounder parameters should be done carefully. A general method for determine the optimum sliding correlator channel sounder already explained in [1]. For ionospheric channel impulse response observations, the implementation of channel sounder using Software Define Radio (SDR) already done in [2][3][4][5][6]. However, the paper that shows the method for design a sliding correlator channel sounder with consideration to the ionospheric channel information from ITU and SDR device specifications are difficult to found by authors. From our perspective, this consideration should be done to guarantee the result from the designed channel sounder are able to obtained three different conditions of the ionospheric channel characteristic in comprehensively, as described by the International Telecommunication Union (ITU) in [7].
In this paper we explain the method for determine the SDR-sliding correlator channel sounder parameters for observing the ionosphere channel characteristic. The ITU ionospheric channel recommendation and SDR device specifications information are used to determine the designed channel sounder parameters values. This activity is a part of research on multi carrier modulation design for ionospheric channel over Indonesia region, which need a comprehensive information of ionosphere channel characteristic. The rest of papers is organized as follows: In Section 2 the dependency of sliding correlator channel sounder and SDR parameters are explain. The proposed method is described in section 3. In section 4, result from the example implementation for low latitude region are shown. Finally, in the last chapter we conclude this paper.

2 Dependencies of Sliding Correlator Channel Sounder and SDR Parameter

The dependencies of sliding correlator channel sounder parameters are explained in Table 1 [1].

Table 1. Sliding correlator capability and its dependencies parameters

Capability	Equation	Dependencies
Maximum Multipath Delay ($\tau_{\max}$)	$\tau_{max} = \frac{L_{PN}}{f_{chip}}$	f_{chip}, L_{PN}
Temporal resolution (T_{res})	$T_{res} = \frac{1}{f_{chip}}$	f_{chip}
Maximum Doppler Resolution (f_{Dmax})	$f_{D,max} = \frac{f_{chip}}{2\gamma L_{PN}}$	f_{chip}, L_{PN}

L_{PN} is the length of Pseudo Noise (PN) bit. f_{chip} is the frequency of chip and γ is the sliding factor. Values of γ will determine the frequency chip on the receiver side (f_{chip}'). For implementation in SDR platform, the parameters that need to be considered are the number of ADC bits, and the sampling rate (Fs) [8]. Number of ADC bits is affecting the Dynamic Range (DR) values and calculate using (1) [9].

$$DR = 20\log_{10}(bit_{ADC}) \quad (1)$$

Based on the DR value, the maximum of PN length (L_{PN}) could be calculated using (2)

$$L_{PN} = 10^{\left(\frac{DR}{16}\right)} \quad (2)$$

The selection of sampling rate values will be affecting the Central Processor Unit (CPU) usage and it's recommended to choose the lowest possible values to achieve the low cost and simple operation concepts. Sampling rate value is depending on the bit rate (R_b) and samples per symbol (sps) that choose in SDR configuration. Calculation of Fs and Rb are explained in (3) and (4)

$$F_s = sps.Rb \quad (3)$$

$$R_b = L.f_{chip} \quad (4)$$

3 Determination of SDR-Channel Sounder Parameters for Ionospheric Channel Probing

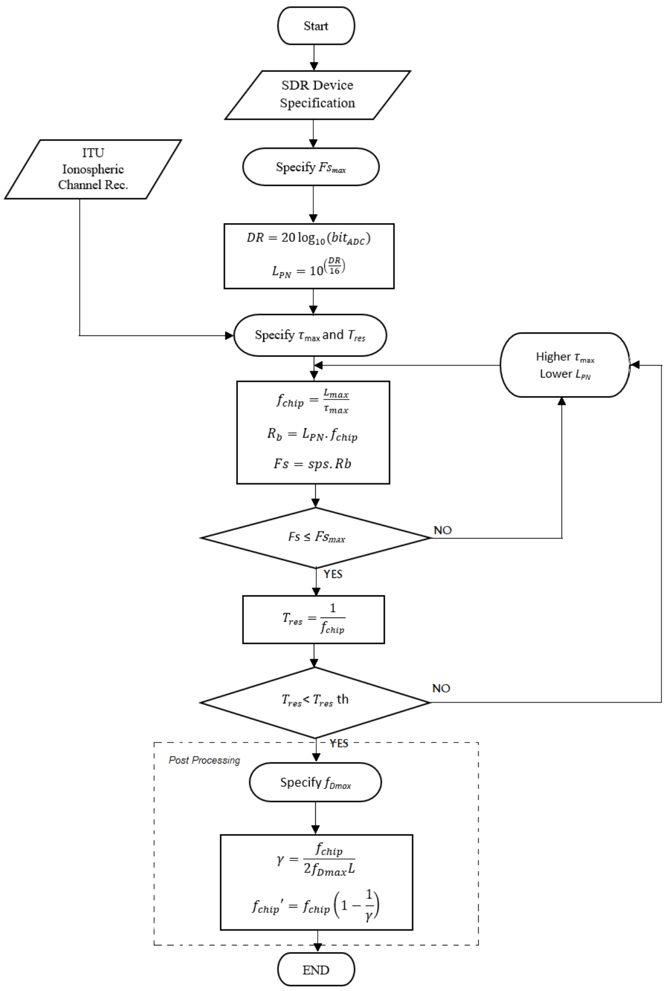

Figure 1. Flowchart for determine the sliding correlator and SDR parameters.

Flowchart for determine the SDR-Channel Sounder parameters is explained in Figure 1. From the SDR hardware specifications, the Fs value is specified with consideration to the limitation of sampling rate maximum of SDR device and CPU usage. The number of ADC bit is use to determine the maximum of L_{PN}. Information from ITU ionospheric channel recommendation is use for specify the τ_{max} and the T_{res}. The parameters of the designed channel sounder system are selected from the adjustment process which involve the Sampling rate maximum and temporal resolution threshold values. For determine the Doppler maximum resolution f_{Dmax}, the parameters of γ could be selected in the form of post processing.

4 Example Implementation for Low Latitude Region

For observing the low latitude ionospheric channel, the τ_{max} is determined by the delay spread values for ionosphere in disturbed conditions. For T_{res}, the delay spread in normal ionosphere conditions is used. SDR device that use is Hack RF one on GNU Radio software. Using flowchart steps in Figure 1, the theoretical capability of the design sliding correlator channel sounder and SDR parameters are describe in Table 2.

Table 2. Theoretical Capability of Design Systems and obtained parameters values

Parameter	Value
τ_{max}	50 milli second
T_{res}	0.196 milli second
f_{chip}	5100
R_b	1300500 bps
L_{PN}	255

Figure 2 show the cross-correlation results of reference signal and received signal. It shows the temporal resolution which is 0.1569 milli seconds. This value is below the theoretical specification which is 0.196 milli seconds and could be accepted. The validation of cross-correlation result could be found from the measurement of chip signal duration as shown in Figure 3, which is 0.1566 millisecond. This result could be used for the next steps activities which is a real observation of low latitude ionosphere channel.

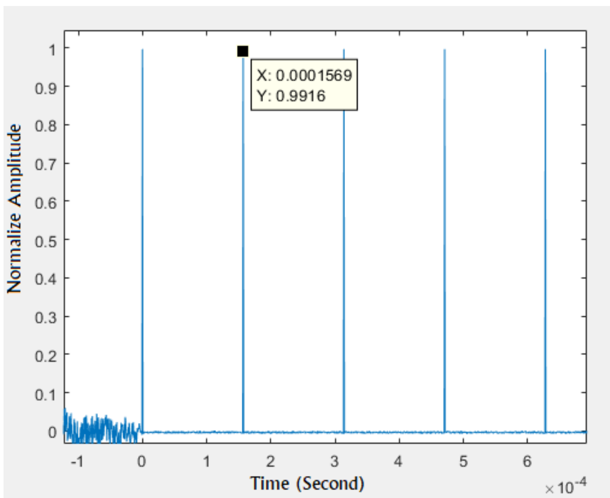

Figure 2. Cross-correlation from implementation results show the delay temporal resolution (T_{res}) value is 0.1569 milli seconds which below the theoretical capability of the design systems.

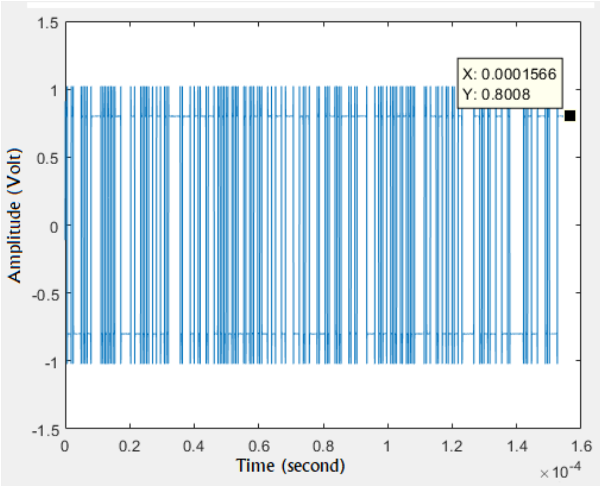

Figure 3. Transmit chip signal with duration is 0.1566 milli seconds as a validation of delay time resolution

5 Conclusion and Future Works

Determination of SDR-sliding correlator channel sounder parameters values has been done using a method that use the ionosphere channel information from ITU and specification of SDR device. The example implementation for low latitude ionosphere region show that the obtained T_{res} result are lower with theoretical capability but still could be accepted. Based on this result, the designed system could be used for observing the real ionosphere channel in low latitude region as the future work.

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7 References

1. R. J. Pirkl and G. D. Durgin, “Optimal sliding correlator channel sounder design,” IEEE Trans. Wireless. Communication., vol. **7**, no. 9, pp. 3488–3497, 2008, doi: 10.1109/TWC.2008.070278.

2. I. Kurniawati, G. Hendrantoro, and P. H. Mukti, “Preliminary Study on HF Channel Complex Impulse Response and Power Delay Profile Characteristics in Low Latitude Region,” September, 2014, doi: 10.13140/2.1.2110.9121.

3. M. Hervás, R. Ma Alsina-Pagès, F. Orga, D. Altadill, J. L. Pijoan, and D. Badia, “Narrowband and wideband channel sounding of an antarctica to spain ionospheric radio link,” Remote Sens., vol. **7**, no. 9, pp. 11712–11730, 2015, doi: 10.3390/rs70911712.

4. P. S. Kennedy, “Design of Software Defined Radio for SuperDARN Radar,” Virgina Polytehnic Institute and State University, 2019.

5. A. Jain et al., “Cross-channel souding for HF geolocation: concepts and experimental results", 2018.

6. V. A. Ivanov, A. A. Elsukov, and M. I. Ryabova, “Measuring scattering function of HF NVIS channel by sounding with the use of a noise-like BPSK signal,” J. Phys. Conf. Ser., vol. 1632, no. 1, 2020, doi: 10.1088/1742-6596/1632/1/012001.

7. ITU-R Rec. F.1487, “ITU-R Rec. F.1487 Testing of HF modems with bandwidths of up to about 12 kHz using ionospheric channel simulators F Series Fixed service,” vol. 1487, 2000.

8. T. Hentschel, M. Henker, and G. Fettweis, “Digital front-end of software radio terminals,” IEEE Pers. Communication, vol. **6**, no. 4, pp. 40–46, 1999, doi: 10.1109/98.788214.

9. S. Arar, “Understanding the Dynamic Range Specification of an ADC,” https://www.allaboutcircuits.com, 2018. [Online]. Available: https://www.allaboutcircuits.com/technical-articles/understanding-the-dynamic-range-specification-of-an-ADC/. [Accessed: 31-Dec-2020].