ResearchGate

See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/publication/220822890

Development and performance assessment of a real time high-resolution RF channel sounder

Conference Paper · July 2011

DOI: 10.1109/IGARSS.2011.6050171 · Source: DBLP

CITATIONS
13

READS
658

2 authors:

David Ferreira
University of Vigo
36 PUBLICATIONS **658** CITATIONS

SEE PROFILE

Rafael F. S. Caldeirinha
Polytechnic Institute of Leiria
298 PUBLICATIONS **2,318** CITATIONS

SEE PROFILE

All content following this page was uploaded by David Ferreira on 18 December 2013.

The user has requested enhancement of the downloaded file.

DEVELOPMENT AND PERFORMANCE ASSESSMENT OF A REAL TIME HIGH-RESOLUTION RF CHANNEL SOUNDER

D. Ferreira and R. F. S. Caldeirinha*†*

*Instituto de Telecomunicações (DL-IT),
Polytechnic Institute of Leiria, Leiria, Portugal
dferreira@mail.co.it.pt, rafael.caldeirinha@ipleiria.pt
†University of Glamorgan, Faculty of Advanced Technology
CF37 1DL Treforest, United Kingdom

ABSTRACT

This paper presents a swept time delayed cross-correlation (STDCC) channel sounder. The proposed topology employs the real-time sliding correlation technique of pseudo-random (PN) sequences, enabling amplitude and Doppler spectrum measurements and analysis of individual multipath components. It makes use of recent technologies, specifically in the generation and transmission of PN sequences, which allows for an easy adjustment of the main specifications of the sounder. The intermediate frequency (IF) stage of the system presented here has been bench-tested and validated by using a PN sequence at 1GHz chip rate, which allows for a time-delay resolution of consecutive multipath components of 2ns. The radio frequency (RF) stage as also been bench-tested, and will be followed by rigorous measurements in an anechoic chamber. The dynamic range of the system was measured to be better than 40dB.

Index Terms— Channel sounder, Sliding correlation, Pseudo-random sequence, Multipath, Power Delay Profile, Wideband.

1. INTRODUCTION

Over the past few years, the world has witnessed a fast and continuous evolution of the information technologies. Nowadays, a trend is becoming visible in the industry in making use of evermore higher frequencies in order to have the required bandwidth, so that new and enhanced telecommunication services can be accommodated. The use of such frequencies raises doubts regarding the propagation mechanisms of electromagnetic waves in various media. It is therefore required to undertake appropriate studies in order to characterise and model those propagation mechanisms.

This paper presents a wideband channel sounder, implemented using the STDCC technique. This method allows for the characterisation of highly dynamic channels, and it can provide both amplitude and Doppler spectra measurements. Some authors, [1] to [3], have already implemented similar channel sounders that operate under this principle, although with different technical specifications between them. For example: in [1] the sounder is limited to a time-delay resolution for consecutive multipath components of 5ns; in [2] the system does not perform the correlation in real time; and in [3] the sounder is not able to measure Doppler spectrum. The topology proposed in this paper makes use of high-speed Digital to Analogue Converters (DAC) up to 1.25GHz, in order to generate, download and transmit the desired PN sequence, which in turns will modulate a highly stable phase lock loop (PLL) carrier. The modulated signal will then be transmitted through the radio channel. The novelty of this topology relies on the fact that one can have full control over the properties of the PN sequence transmitted, simply by uploading the desired vector into the DAC's driver.

2. SLIDING CORRELATION TECHNIQUE

The STDCC technique, also known as the sliding correlation, was first implemented by Cox in 1972 [4]. This technique is based on the auto-correlation properties of PN sequences. The PN sequences commonly used in STDCC sounders are of the type MLSR (Maximal Length Linear Shift Register) [1], [2].

By adjusting the receiver PN sequence clock slightly slower than the PN clock on the transmitter, the two sequences will "slide" against each other. When both sequences are perfectly aligned in time, the correlation output will have its peak value. Otherwise, when the sequences are not aligned, the correlation result will have its minimum value. Fig. 1 depicts the auto-correlation of a PN sequence.

In a radio channel, different multipath components, which exhibit different propagation paths and delays, will maximally correlate at different instants in time [1].

This work was partially supported by Fundação para a Ciência e a Tecnologia (FCT), under pluriannual funding and research project PTDC/EEATEL/099973/2008–ADCOD.

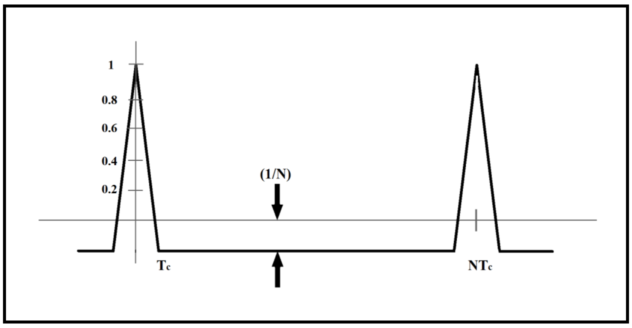

Figure 1. Auto-correlation of a PN sequence.

Although the channel multipath components typically arrive at the receiver with different time delays, in the order of nano seconds, the “sliding” property of these systems spreads out in time those components at the output of the correlator [4]. The amount by which the correlation peaks are time dilated is described as sliding factor, and is represented by (1),

$$k = \frac{f_T}{f_T - f_R} \quad (1)$$

where f_T is the transmitter PN chip frequency, and f_R is the receiver PN chip frequency. Hence, when considering a transmitter PN sequence clocked at 100MHz, and a receiver PN sequence clocked at 99.999MHz (which yields to a sliding factor of 100000), a 20ns correlation pulse $(2T_c)$ will be displayed at the output of the system as a 2ms pulse. This is also known as time dilation.

According to [1], the theoretical dynamic range of a STDCC sounder can be specified as (2),

$$D_R = 20\log_{10}(N_{PN}) \text{ dB} \quad (2)$$

where N_{PN} is the PN sequence length in chips.

3. TRANSMITTER BLOCK

The transmitter block diagram of the channel sounder is depicted in Fig. 2. The main components are described next.

3.1. Tx Clock Generator

The required clock signal for the PN generator is synthesised using the development board of the RF2052 wideband RF chip, from RFMD. This device can provide an output from 300MHz to 2.4GHz, and is configured using a proprietary application.

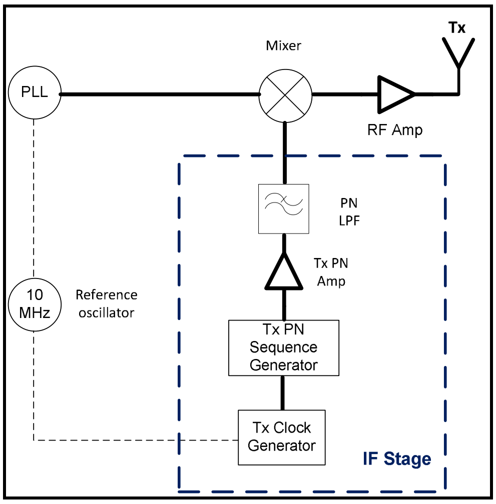

Figure 2. Transmitter block diagram of the sounder.

3.2. Tx PN Sequence Generator

The PN sequence generator consists of two different devices, a high-speed DAC driven by an appropriate digital driver/loader.

The DAC used is the development board for the AD9739 chip (AD9739EBZ), from Analog Devices. It has a maximum sampling rate of 2500MSPS and 14 bits resolution.

The driver/loader for the DAC is also from Analog Devices and is designated as Data Pattern Generator 2 (DPG2). This device has a maximum rate of 1.2GSPS.

4. IF RECEIVER BLOCK

The receiver block diagram for the channel sounder is illustrated in Fig. 3. Detailed description of the main blocks used in the receiver section of the sounder, from left to right, will be provided, except for the ones which are in common with the transmitter block which have already been described.

4.1. I/Q Downconverter

In order to analyse Doppler spectrum, in-phase and quadrature components of the received signal are thus required. For this purpose, the HMC-C009 mixer from Hittite has been chosen. This mixer has a RF/LO frequency range of 4 to 8.5 GHz, IF range of DC to 3.5GHz and 7.5 to 10.5 dB conversion loss.

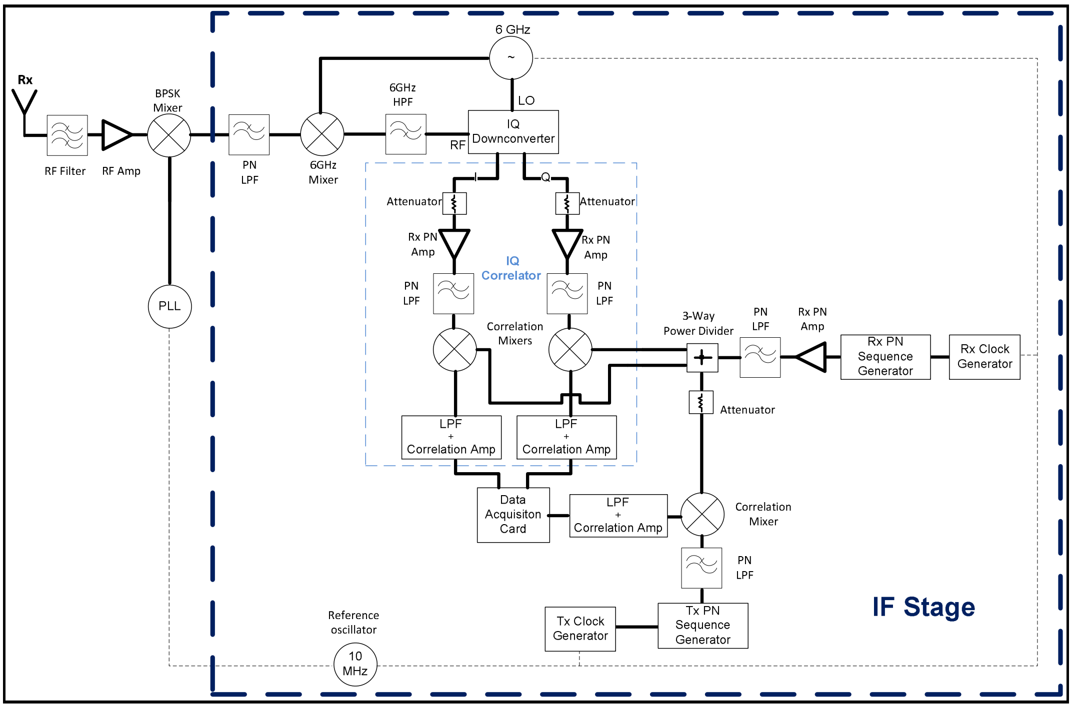

Figure 3. Receiver block diagram of the sounder.

4.2. Correlation Mixer

The mixer that enables the sliding correlation of the PN sequences is the ZFM-2-S+ from Mini-Circuits. This mixer provides a RF/LO range of 1 to 1000 MHz, a DC to 1000MHz on the IF port and 5.7 to 7.5 dB conversion loss. The DC lower band on the IF port is a system requirement, as the output of the correlation will have a very low frequency, in the order of a few kHz.

5. BENCH TESTING OF THE IF SYSTEM

A bench method was developed in order to assess the performance of the IF stage, as depicted in Fig. 4. With this setup, which allows for different multipath lengths and losses, one can evaluate the IF stage performance on multipath resolution and dynamic range.

5.1. Setup

The main sounder specifications for this test can be observed in Table I. The propagation speed on the coaxial cables is of 70% the speed of light, as per their datasheet.

This paper only shows one of the many tests executed with the setup depicted in Fig. 4, which is detailed in Table II and has the purpose of evaluating the sounder multipath resolution.

Providing that the cables/paths #1 and #3 used in the tests have always the same length, it will be path #2 that will assess the sounder multipath resolution, more specifically the resolution for consecutive multipath signals. Table III specifies the expected time delays for the signal travelling in paths #2 and #3 in respect to path #1.

By performing a system calibration previously to executing these tests, the real-time data obtained by the DAQ card can be converted to an approximate level of power at the receiver input port.

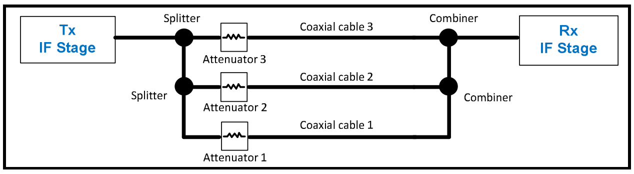

Figure 4. Depiction of the bench testing method for the IF system.

TABLE I. MAIN SOUNDER SPECIFICATIONS

Parameter	Value
Transmitter PN chip frequency	1GHz
Receiver PN chip frequency	999.995MHz
Chip period	1ns
PN sequence length	2047 chips
Post-correlation signal bandwidth	10kHz
Sliding factor	200000
Theoretical dynamic range	66dB
Multipath time resolution	2ns
Multipath spatial resolution (cables)	0.42m
Maximum measurable delay	2.047μs

TABLE II. PATHS SIMULATED IN EACH BENCH TEST

Test #	Cable 1	Cable 2	Cable 3	Att. 1	Att. 2	Att. 3
1	20cm	60cm	15m	20dB	30dB	15dB

TABLE III. EXPECTED TIME DELAYS FOR MULTIPATH SIGNALS

Cable length	Time delay in respect to path #1
Path 2 – 60cm	1.91ns
Path 2 – 80cm	2.86ns
Path 3 – 15m (measured 14.89m)	69.95ns

5.2. Test 1 results

This test is intended to evaluate the theoretical 2ns multipath resolution of the sounder. The expected power levels for paths #1, #2 and #3 are -38.8, -49.2 and -33.8 dBm, respectively. Fig. 5 depicts the Power Delay Profile, or PDP, for test 1, and Fig. 6 shows only the two first multipath components.

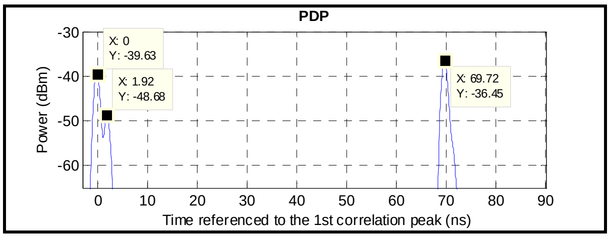

Figure 5. Measured PDP at receiver input port for test 1.

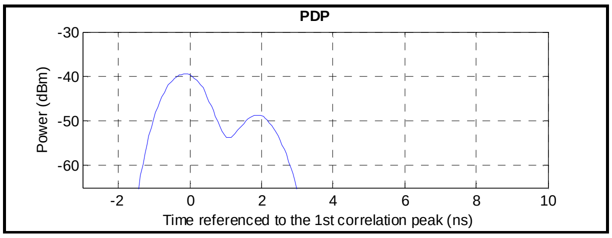

Figure 6. Detail of measured PDP at receiver input port for test 1.

6. RF STAGE SOUNDER PERFORMANCE

The fully integrated sounder, with both IF and RF stages, was briefly tested in a back-to-back bench method, as shown in Fig. 7, with the corresponding results being presented in Fig. 8. The latter figure shows only a small time frame of the actual measurement, and the two correlated path contributions actually correspond to the periodic repetition of the PN sequence being transmitted.

Due to a malfunction on one of the 18GHz RF components, it was not possible to perform more measurements with the complete system (both indoor and outdoor) in time for this paper submission.

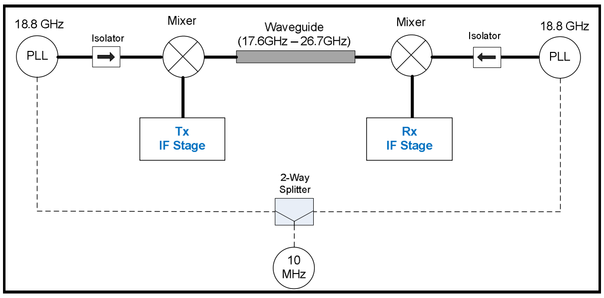

Figure 7. Depiction of the test method for the fully integrated sounder.

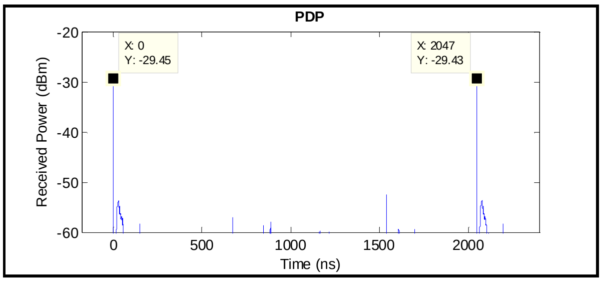

Figure 8. Measured PDP for the RF bench test of the sounder.

7. CONCLUSIONS

This paper proposes a topology for a channel sounder, employing the STDCC technique of PN sequences by hardware and in real time. The performance of the IF stage has been carefully assessed with measurements. Results have demonstrated that the proposed topology is capable of resolving very close multipath components, with a time resolution better than 2ns.

Preliminary bench tests of the sounder fully integrated with the IF and RF (18GHz) stages attest for its correct operation, and it is safe to assume that real indoor and outdoor measurements should perform at least similarly. Also, a 60GHz RF system is also planned to be integrated with the IF stage of the sounder.

8. REFERENCES

[1] C. R. Anderson, "Design and Implementation of an Ultrabroadband Milimiter-Wavelength Vector Sliding Correlator Channel Sounder and In-Building Measurements at 2.5 & 60 GHz", Masters Thesis, Virginia Polytechnic Institute and State University, 2002.

[2] A. V. Alejos, "Measurement, Characterization and Modeling of the Radio Channel for Broadband Multimedia Systems at 40GHz", Tesis Doctoral, Universidade de Vigo, 2006.

[3] T. Takeuchi, M. Tamura, "A Ultra-Wide Band Channel Sounder for Mobile Com-munication Systems", 12th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, 2001.

[4] D. C. Cox, "Delay Doppler Characteristics of Multipath Propagation at 910 MHz in a Suburban Mobile Radio Environment", IEEE Transactions on Antennas and Propaga-tion, vol. AP-20, No. 5, pp. 625-635, 1972.

View publication stats