Demonstration of a Software Defined Radio Platform for dynamic spectrum allocation.

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Abstract— **This paper describes a proposed demonstration of a Reconfigurable Radio platform in order to be used in the areas of cognitive radio and dynamic spectrum allocation. The platform is currently under development in the Institute of Microelectronic and Wireless Systems (IMWS), Maynooth as part of the CTVR effort in cognitive radio systems. The platform operates in across the frequency band from 1.6GHz to 2.5GHz with the capability to support the GSM1800, DCS1800, PCS 1900, UMTS-FDD, UMTS-TDD and 802.11b standards. This demonstration will display the platforms capability to sense a particular channel, and identify the modulation scheme and communications standard in operation. It will also show the system's capability to move from one channel to another and implement arbitrary modulation schemes in these channels in both transmit and receive mode.**

Index Terms— **SNR, Spectrum, Rx, Tx, Direct-conversions, DSA.**

I. Introduction

The demonstration platform consists of a transmit section, receive section and baseband section which is connected to a laptop computer via a USB 2.0 interface, that implements the software element of the platform. The control plane functions for the transmitter, receiver and baseband sections are managed by an 8051 microcontroller on the baseband board, while all signal processing and modulation functions are implemented in software on the laptop computer. The software function has the ability to interface with commercially available products such as MATLAB allowing the rapid development and testing of experiments on actual hardware. As such this platform provides an invaluable research tool for the fields of cognitive radio and dynamic spectrum allocation.

II. Description

A. Primary Technical Goals of the Platform

The main purpouse of this platform is to cover a wide range of wireless standards without any change in the hardware. The hardware will adapt to these standards requirements through the programmability of its software. The primary goal of this platform was to cover all the requirements for the whole spectrum allocation. However the different characteristics between the standards in some radio frequency parameters made that idea impossible to achieve with the available technology. Signal levels , sample rate, and noise figure are some of the parameters which demand different requirements depending of the standard. Therefore, due to the incompatibility between air interfaces, a study of the standard was done in order to separate them in groups with similar characteristics. These groups and its characteristics are described below:

1) IEEE 802.15.4a and Bluethooth: low data rate (¡ 1Mbit/s), short range, and transmitted power less than 1mW.
2) IEEE 802.15x and UWX: high data rate (up to 500Mbit/s), short range, low transmitted.
3) IEEE 802.11x, GSM, DCS 1800, PCS 1900, UMTS/CDMA, and IEEE 802.16x: Delivery of a range of bits rates to the end user over long distances.

Considering the last group as the most demanded and with similar constraints on the radio, it has been the target for this platform.

B. System operational parameters

The system operational characteristics are the result of studying the requirements for each specification. Thus the calculation of the necessary parameters for both base band and radiofrequency blocks are done to match the standards limitations.

1) RF Specifcations: It is difficult to generate specifications for SDR for use in DSA because of its schemes are only in the experimental stage, no set of coherent requirements exist yet. The parameters of interest for the design of the platform in order to match the standards requirements are: receiver sensitivity, receiver third order intermodulation product (IP3), receiver noise figure(NF), transmitter power levels and transmitter phase noise. These parameters depend of the blocking performance of the receiver, the mask of the transmitter and the expected bit error rate (BER) in each particular standard. In order to generate a range of limitations for the platform, the parameters of interest for each particular standard covered by the system are studied. These values are described below:

TABLE I

Standards	Sensitivity (dBm)	NF (dB)	IP3 (dBm)	Tx Output Power (dBm)	Tx Phase Noise (dBc/Hz)	SNR (dB)
GSM	-102	9	-18	39	-154	10
DCS 1800	-100	11	-18	36	-154	10
PCS 1900	-102	9	-18	36	-154	10
UMTS	-117	9.6	-21.3	33	-148	7
802.11	-76.5	11	-22.5	41	?	10
802.16	-91	7	?	36	?	9.8

According to this table GSM is the most restrictive standard and consequently most of its parameters will describe the limitations of this system. Thus, the constrain which characterize the platform are:

1) Receiver Sensitivity:-117dBm
2) IP3: -21dBm
3) Noise Figure: 9dB
4) Transmitter phase noise: -154dBc/Hz

In relation with the previous values and doing the correspondent calculations for the receiver and transmitter parameters, the specifications for the RF performance of the platform are given in table II. The frequency capabilities of the platform are adapted to the available spectrum allocation at the DySpan conference. Therefore, the receiver will capture signals in the frequency range from 1.6 GHz to 2.5 GHz, which is covering the both 11 and 12 channels. Consequently the transmitter will transmit two different signals at frequencies:2.056 GHz and 2.231 GHz which are the center frequencies for both channels.

2) Base Band Specifcations: The base band block of this platform is in charge of providing an optimum digitization, fast sample rate convertion and reliable synchronization for the system. Hence, the specifications of this block are directly correlated to the incoming and outcoming signal characteristics. Spurious emission rejection for the transmitter and blocker features for the receiver are parameters to consider since they decide the dynamic range of the signal and, in consequence the dynamic range limitations for the base band board. The base band specifications for this sytem are described below:

1) ADC resolution: 16bits
2) DAC resolution: 16bits
3) ADC Sample rate: upto 100Msps
4) DAC Sample rate: upto 200Msps
5) ADC Sample convertion time: 7 clock cycles
6) DAC Propagation delay time: 1.1ns
7) PC link standard: USB2.0
8) Microcontroller: 8051
9) Data rate: upto 480Msps

III. Demonstration Description

3) Reconfigurable process: During the experiment the receiver will monitor a signal with in range of 1.5GHz to 2.6GHz and identify the carrier frequency. Then the receiver will downconvert the signal and digitize it. The software will be then able to identify the signal and demodulate it. The fact that most of the components at the receiver are broad band devices enables the sweep of frequencies over a very wide range. The signal characteristics are analyzed by digital signal processing since the signal is driven from the base band board to the computer.

In the same way as the receiver, the transmitter will receive the desired signal to sent from the base band

TABLE II
Platform Specifications

Receiver	**Transmitter**
IIP3: -0.87dBm	P_{out}: 30dBm
Sensitivity: -104dBm	PN: -152dBc/Hz
BW: 22MHz	BW: 22MHz
NF:7dB	

block and will performs the up conversion process. The phase-locked loop(PLL) outputs a signal with the desired center frequency to the mixer which produces the final transmitted signal to the next amplification and filtering stages up to the antenna. During all this process the base band block will sent three kind of signal to both receiver and transmitter front end:

1) Data signals: composed by information such as modulation, bandwidth, power level, data rate, center frequency etc. They are sent from the software to both RF front ends. These signal are the base of the reconfigurability of the system since they are the responsible to change the capabilities of the platform.
2) Control signals: composed by enable signals to turn on and off the different devices on the platform in order to achieve a reliable synchronization between the information exchange.
3) Management data signals: composed by address in order to enable different memory location to write the data signals.

While all these information, control and management signals are performed the reconfigurable process is being achieved. A diagram of the reconfigurable process is shown in figure 1.

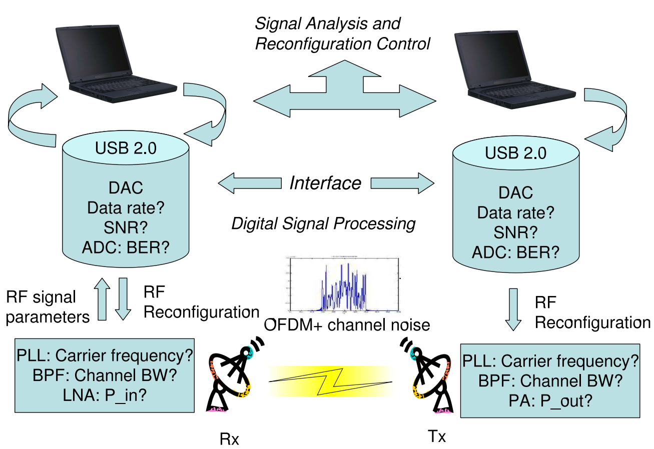

Fig. 1. Reconfigurable process.

4) Platform design: The direct conversion architecture is used for the design of this SDR since it requires low power dissipation and easy implementation and in consequence small size. This technique transform the RF signal to zero frequencies at down-conversion and from zero frequencies to RF at up-conversion using just one conversion stage. Thus the result is a goos image suppression characteristic. The platform is divided into three functionality blocks: radio frequency receiver, radio frequency transmitter and base band interface; in order to meet the requirements for each particular block according to their working frequencies. A block diagram of the system is illustrated in figure 2.

The physical design of this system is presented in

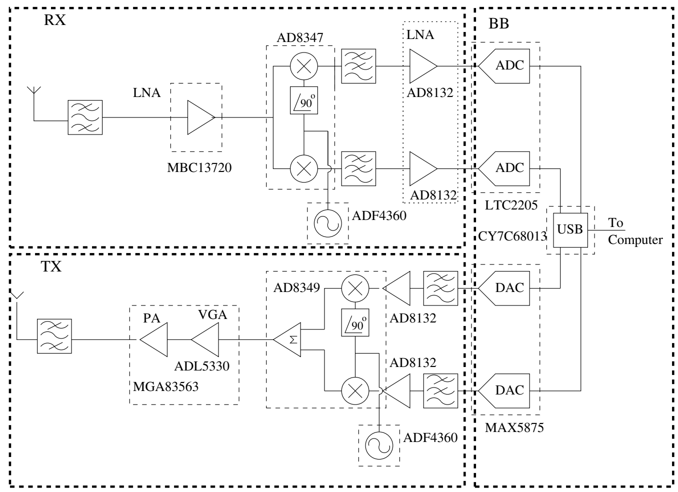

Fig. 2. Block diagram of the system.

figure 3

5) Simulation and Test Results: The software part of the platform is implemented usin Matlab, the Matlab environment communicates with the hardware using and special driver within Matlab. To monitor the eye diagram and constellation of the signal, the data is captured from the oscilloscope and analyzed with simulink as is show in figure 4.

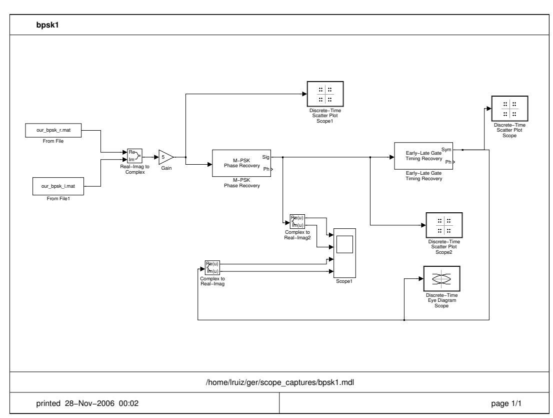

Fig. 4. Data monitoring platform.

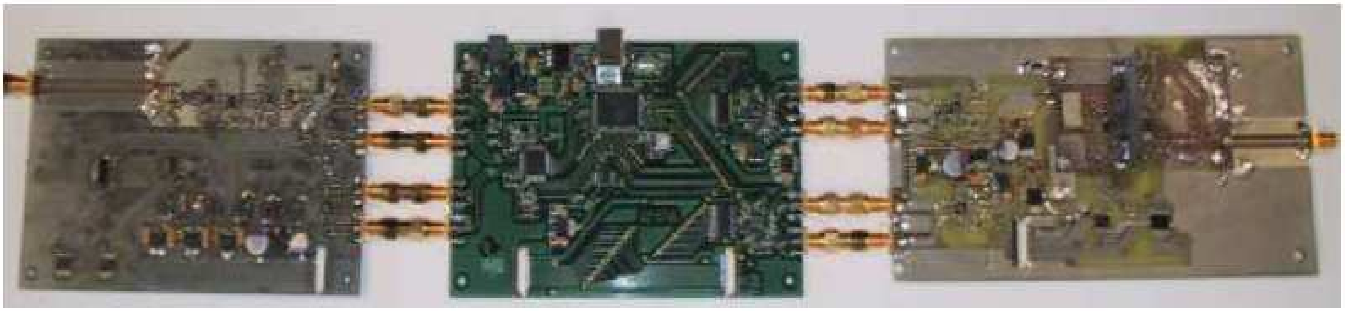

Fig. 3. SDR Platform.

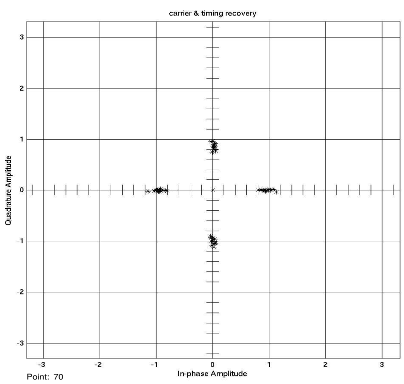

Fig. 5. Received QPSK constellation.

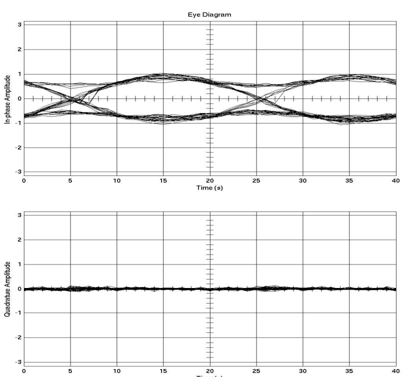

Fig. 6. Eye diagram for a bpsk received signal.

IV. Technical Significance

This platform has a very considerable impact in a wide band of communication technologies. However the most important influence is in Spectrum allocation. Since the allocation band plan is independently regulated en each country, there is different frequency bands for different countries and in consequence an inefficient use of the spectrum. Here SDR play a big role due to its capability of adaptation to the designer purposes and the regulator purposes.

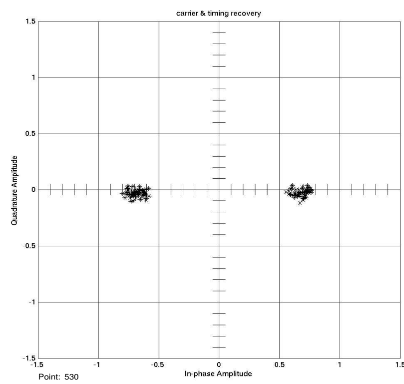

Fig. 7. Received bpsk constellation.

On the other hand, according to the applications where SDR can be used, they are described below:

1) Radio Communications: It is one of the most important application since the problem of interoperability between various agencies is solved with SDC because of the spectrum consumption is reduced to minimum levels. In addition some standards such as GSM and LAN require high speed data processing that is possible to implement with a SDR platfrom.
2) Medical Radio System: The ability of SDR to adapt to environment changes permit as well to update functions in medical equipment quickly and easy.

To finish with th technology impact, this platform is the first step to develop highest performed SDR platforms. It has been developed as fast as possible, with the available technologies and application at the Institute of Microelectronics and Wireless Systems. This gives to operators, subscribers, designers and regulators a basic idea of the functionalities and advantages of SDR. The experiment will shows to the audience the adaptability of the Hardware to the allocated frequencies.

V. Maturity and Operational Capabilities

The presented platform is the first prototype constructed. Since the platform must meet all the blocker specifications for the standards, filter design is one of the most difficult task to achieve in this prototype. For this reason it is still in development to improve the reflection characteristics and attenuation.
According to silicon, some silicon prototypes are being developed for the front end of the system, however they still in test. One of the silicon prototypes in test for this platform is a combined LNA and Mixer to reduce the noise figure of the system.
In relation to the software, for a first approach it has being implemented using Matlab on standard PC platform. However the next generation of the prototype will use FPGA. USB2.0 bandwidth is not enough because of it can not get enough data over the USB bus. Therefore eSATA (external Serial ATA) interface to connect to the computer is considered to implement in the next generation. Digital Signal Processing (DSP) capabilities will be added to hardware in future prototypes to lower data transfer rates.

VI. Logistical Needs

VII. Conclusion

In this paper a basic description of a software defined radio platform is presented. The adaptability of the system in channel bandwidth, bit rates, IP3, and sensitivity permits it to work within the desired group of standards. It achieves the basic requirements for experimentation in Dynamic Spectrum Allocation across a width range of application.

VIII. Acknowledgments

This work is carried out as part of the CTVR (Center for Telecommunications Value-Chain-Driven Research) funded by SFI(Science Foundation Ireland) at the Institute of Microelectronic and Wireless Systems, NUIM.

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