DIGITAL PRE-DISTORTION LINEARIZER FOR A REALIZATION OF AUTOMATIC CALIBRATION UNIT

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ABSTRACT

Software Defined Radio (SDR) seems to be the best solution for global roaming of mobile communication throughout the world. But the RF reconfigurability of SDR does not always guaranty its compliancy with the radio-regulation. To solve this problem, the Federal Communication Commission (FCC) proposed Class III permissive change (C3PC) for the type approval procedure of SDR [1]. Unfortunately, since all of the combinations of HW and SW sets should be approved in C3PC, this might burden hardware (HW) and software (SW) manufactures, in addition to the Telecommunication Certification Body (TCB) with troublesome type approval procedures. Thus, it reduces the flexibility of SDR. To enhance the flexibility, we proposed the Automatic Calibration Unit (ACU) and its ACU eMployed Authorization Procedure (AMAP) [2]. Being a hardware module manager, ACU controls and adjusts the analog RF circuit adaptively, while ensures that SDR terminals comply with the radio regulation by a run-time check. AMAP provides a dynamic certification procedure that enables the Hardware and the Software of SDR to be certified separately, resulting in the improvement of the SDR flexibility.

Keywords: Automatic Calibration Unit (ACU), ACU eMbedded Authorization Procedure (AMAP), Digitally aided Adaptive RF (DARF), Digitally aided Secure RF (DSRF)

1. INTRODUCTION

In today's mobile telecommunication, there is no global standard throughout the world. Several solutions to this problem include recent 3G standardization. Another option to solve the unification of mobile communications is the Software Define Radio (SDR). With powerful Digital Signal Processors (DSP) and Field Programmable Gate Arrays (FPGA), it is possible to build an universal mobile phone that can be reconfigured from country to country. Besides cross-country compatibility, SDR also provides upgradability to the mobile phone. This includes software bug fixes for radio components, addition of new modulation schemes, and so on. However, with present technology of the A/D/A converters, it is impossible to process RF component in the digital domain due to high sampling rate and too much power consumption. Also, if A/D/A converters were placed too close to the antenna, they would convert a lot of useless signals together with the desired signal [3]. Therefore, for practical reasons, in our previously proposed Automatic Calibration Unit (ACU), it includes Digitally aided Adaptive Radio Frequency (DARF) components. By feeding output signal of the transmitter back to the ACU, it can process the signal digitally and adjust the RF components adaptively. An example of the DARF is the bias control of an amplifier with a digital predistortion linearizer, which will be further illustrated in this paper. Besides functioning as an adaptive RF module manager, the ACU also performs radio security checking. It is a run-time check, which makes sure the combination of Software (SW) and Hardware (HW) is compliant with the radio regulation.

2. ACU AND AMAP

2.1 ACU

ACU has been proposed to be a new security system to maintain the stability and compliancy of SDR terminals when they are operated or reprogrammed to new operating parameters. ACU is a hardware embedded module that controls all of the RF operating parameters such as frequency, bandwidth or output power within regulation boundaries. It will be placed between the digital baseband circuit (programmable baseband) and IF/RF analog circuits as described in Figure 1.

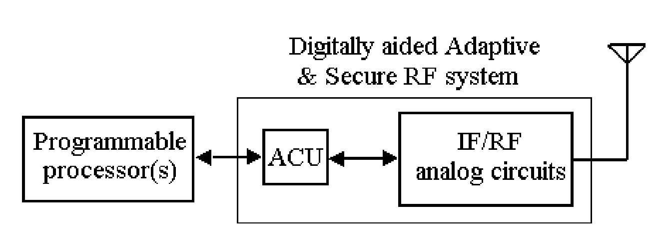

Fig. 1: Positioning of ACU module in SDR architecture

As mentioned before, the ACU can be considered as a RF module manager. The main functions of the ACU are:

1. Digitally aided Adaptive RF system (DARF):
   Since it is not possible to build a digital RF component due to high sampling rate, in our proposed SDR platform, a digitally aided adaptive RF system is used. Being the digital part of the adaptive RF, ACU controls and adjusts the analog RF components. For example: ACU has a predistortion linearizer and a bias control for the amplifier.

   - Bias control of amplifier: The bias voltage of an amplifier can be adjusted to achieve better amplification efficiency based on the Peak to Average Power Ratio (PAPR) of the input waveform.
   - Pre-distortion linearization: The input waveform can be pre-distorted to cancel out the non-linear distortion generated in the amplifier.

   This example of digitally aided adaptive RF is shown in figure 2.

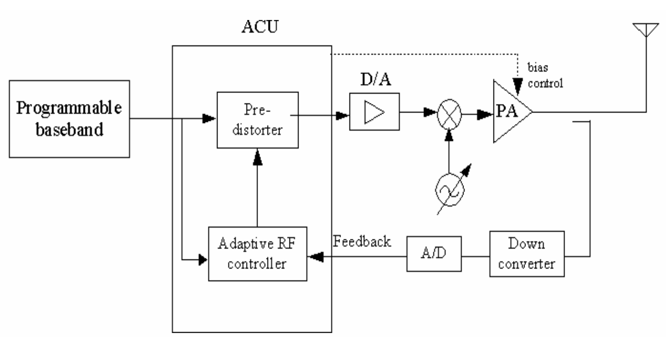

Fig. 2: Digitally aided Adaptive RF system of ACU

2. Digitally aided Secure RF system (DSRF):
   In our proposed architecture (2.2 AMAP), the authorization body approves the SW and the HW separately. Therefore, to make sure that combination of HW and SW complies with radio regulations, ACU performs a run-time radio-regulation validation check.

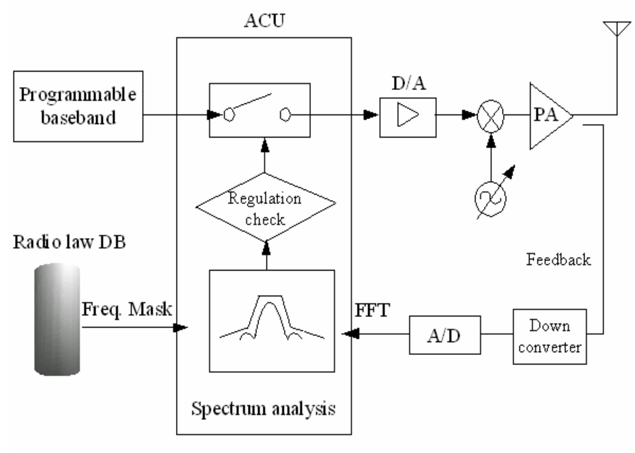

Fig. 3: Digitally aided Secure RF system of ACU

As shown in figure 3, a small portion of the RF analog circuit output is coupled into a down converter and converted to digital signals. The power spectrum characteristic of this signal is then calculated by the spectrum analysis module (FFT), which is implemented within the ACU. The result is compared with the data stored in the Radio law Database to ensure that the system complies with the regulations. This is performed when the system is operating.

2.1 AMAP

Our proposed AMAP enables hardware and software to be authorized separately. To ensure radio compliancy when both HW and SW are functioning together, the ACU performs a run-time radio regulation check. Thus, we could separate the authorization parameters into SW only, HW only (including ACU), and combination of SW and HW parameters. The concept of AMAP authorization procedure is shown in figure 4 below.

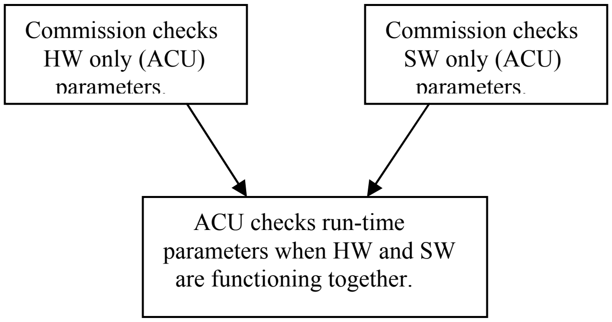

Fig 4: AMAP model of authorization process

After the SW is authorized by the Telecommunication Certification Body (TCB), it produces a digital certificate, which is to be downloaded together with the SW itself.

3. PROCESS OF LOADING SOFTWARE

Below, there is an example of how ACU employed SDR terminal works.

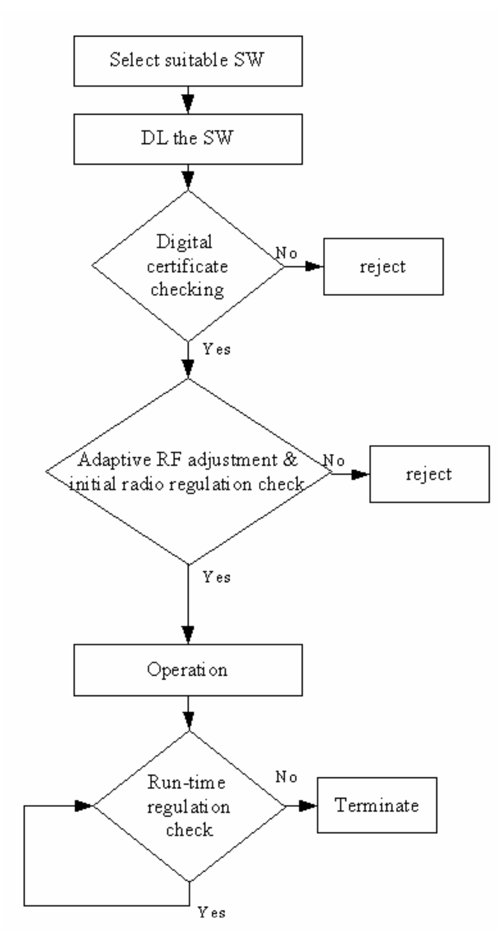

Fig. 5: Software installation flow chart

When new software is downloaded via the service provider and installed in SDR terminal, the system checks whether it complies with the radio regulation before utilization. The software installation flow chart is described in Figure 5.

1. Select suitable SW package: suitable SW package is selected by comparing the software requirements and hardware requirements. Only software that fits the hardware requirement can be downloaded.
2. Digital Certificate check: SW is verified with its digital certificate from the TCB. This prevents the downloaded SW from being illegally modified and eliminates errors in the downloading process. If the verification is fail, then it should never allow the SW to run on the HW.
3. Download (DL) radio-law Database (DB): the radio regulation parameters are downloaded and stored in ACU Internal Memory.
4. Adaptive RF adjustment & initial regulation check: ACU adjusts the adaptive RF components of terminal by pre-distorter and amplifier bias control. Firstly, ACU runs a pilot signal through the RF components. By adjusting the pre-distorter and bias of amplifier, ACU adaptively adjusts to produce the desired RF signal. An initial radio regulation check is performed before the system is set to operate.
5. Operation: the system is set to operate with this combination of SW and HW.
6. Run-time regulation check: RF signal is feed-backed to calculate the center frequency, output power, out-of-band emission, and etc. These are then compared with the regulatory parameters stored in ACU Internal Memory. This process checks the compliancy of the set of hardware and software in SDR terminal. If it does not obey the radio law, ACU forces RF component to terminate the operation.

4. SIMULATION EXAMPLES

A simulation of ACU module with digital pre-distortion linearizer is performed here in Matlab Simulink as an example.

In this simulation, the prototype of ACU module is shown in the figure 6. It performs the functions of monitoring, adjusting and checking the output of RF analog circuits. The simulation parameters are described in Table 1.

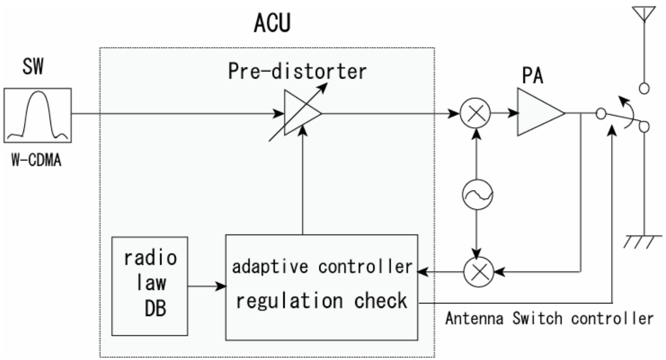

Fig. 6: Functional diagram of ACU prototype

Table 1: Simulation parameters

Parameters	Metrics
Chip rate	3.84 Mcps
Bandwidth	5 MHz (W-CDMA)
Modulation scheme	QPSK

Figure 8 shows the Simulink Model of the simulation. The building blocks of ACU module include two major parts. One is the digital pre-distortion linearizer (digital PD) block for compensation of the distortion of the transmitter signal and the other one is the DSRF block for the radio regulation check.

Initially, the antenna is disconnected from the output of RF components by using an antenna switch. A signal is sent from the baseband module (Software) to the Power Amplifier (PA). The output signal of the PA is feedbacked to the digital PD for analyzing the non-linear characteristic of the PA. Then, the manual switch is connected to the digital PD so that it can compensate the non-linear distortion of the PA. The corrected signal is then fed to the DSRF block (Fig. 8) for run-time regulation check. In this simulation, ACU only checks the Bandwidth and the Adjacent Channel Power Ratio of the transmitter. These parameters are compared with the regulation parameters (from radio law DB) for the compliancy. When the run-time regulation check is passed, the Antenna Switch is activated to make the SDR terminal operate.

The frequency spectrum of the RF output with and without the digital PD is plotted in figure 7. The result shows that without the digital PD, the out-of-band emission is about –20dB. By using the digital PD included in the ACU, the out-of-band emission can be suppressed to a figure less than –45dB. It enables high RF amplifier power efficiency and low out-of-band emission simultaneously.

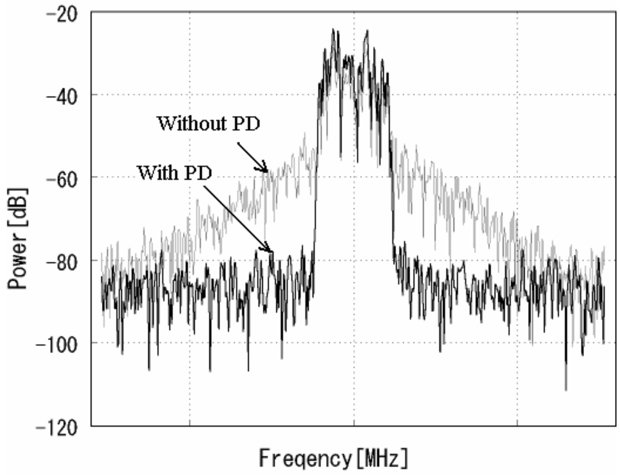

Fig. 7: RF output power spectrum with and without PD

In this simulation, the ACU adjusts the RF components adaptively to produce the desired signal. In other words, DARF of ACU functions like a RF module manager.

5. SUMMARY

Two important functions of ACU, i.e. Digitally aided Adaptive RF and Digitally aided Secure RF were discussed. RF components were adjusted adaptively by DARF of the ACU (a digital pre-distortion linearizer). The radio regulation check was performed by DSRF of ACU to the output of the transmitter. AMAP was proposed to authorize the software and hardware separately in order to improve SDR flexibility without sacrificing its security. Process of loading new software with ACU was discussed.

6. FUTURE WORK

We plan to implement ACU in a test platform to examine its practicability. Also, a more detail structure of AMAP will be established in accordance with ACU.

ACKNOWLEDGEMENT

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7. REFERENCES

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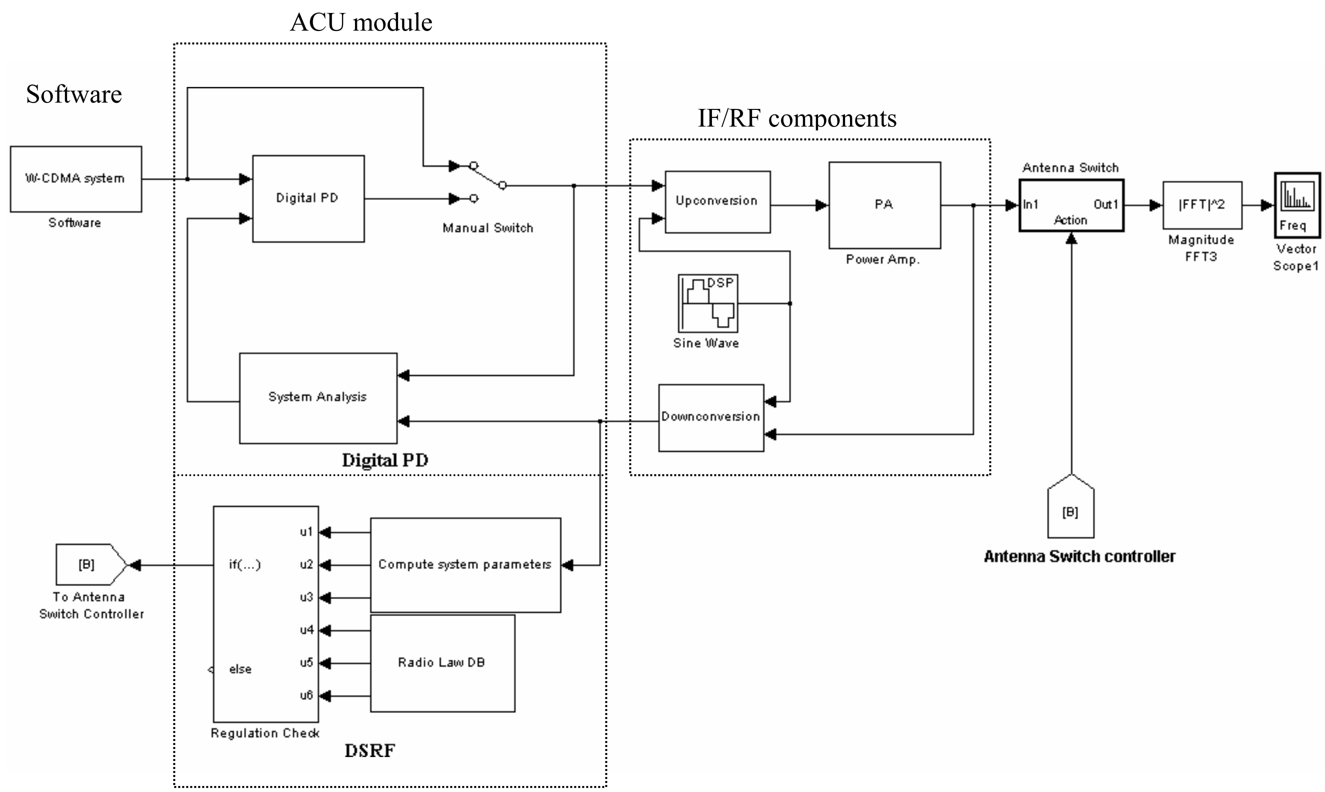

Fig. 8: W-CDMA system with ACU module (Simulink Model)