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A Novel Scheme to Design Software-Controllable Vector Microwave Signal Generator and its Application

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Abstract: With the rapid development of wireless communications, there will be many communication standards in the future, which may cost much to buy the corresponding vector microwave signal generator. Hence, this study investigated a novel vector microwave signal generation method, which modeled the vector baseband signal by the CAD software (Agilent ADS) and then control the conventional microwave signal generation hardware to output vector microwave signals. Compared with the specified vector microwave signal generator developed by Agilent, Anritsu, etc., our software-controllable microwave signal source is cheaper, more flexible and more convenient. Moreover, as an application of our method, we model and realize the TD-SCDMA baseband signal corrupted by multipath channel and Additive White Gaussian Noise (AWGN) in ADS software and then control the hardware (Agilent E4432B) to generate the TD-SCDMA microwave signals. The measurements of the TD-SCDMA microwave signals approve the validity of our method.

Key words: Vector microwave signal source, CAD, software controllable, TD-SCDMA

INTRODUCTION

With the rapid development of mobile communication technology, people's needs for high-speed-data and multimedia service rise quickly, which results in the emergence of the third generation (3G) and the fourth generation (4G) mobile communication systems, such as TD-SCDMA and 3GPP LTE (Chen *et al*., 2002; Li *et al*., 2005; Liu *et al*., 2006; 3GPP, 2007, 2009; Peng and Wang, 2009). However, in the process of developing these communication systems, different standards require different test solutions, such as the vector microwave signal source (generator), which may compel the communication equipment manufacturers to buy many specified signal sources. However, the signal sources provided by the major manufacturers are very expensive (Agilent, 2008; Anritsu, 2008). For example, the TD-SCDMA microwave signal can be generated by Agilent E4438C (about forty thousand dollars), yet some cheap but out-of-date signal sources, such as Agilent E4432B, cannot generate TD-SCDMA microwave signal directly.

In order to tackle the above problem, we need to find a way to design precise, flexible and low-cost signal sources. Accordingly, we propose to use Agilent ADS software to model the vector baseband signals and the fading channels and then control the conventional signal source to generate vector microwave signals. Such a microwave signal generator will take the advantages of flexible increase/decrease function modules, real-time software controllability and multi-standard extensibility. As an application of our method, a TD-SCDMA microwave signal source is taken into account and the test results approve our design.

SYSTEM DESIGN SCHEME

Structure of novel signal source: Figure 1 shows the system diagram of the novel microwave signal generator, where the software module, consisting of ADS (Agilent: advanced design system) and MATLAB, is applied to model, simulate and verify the signal and the fading channel, while the hardware module, consisting of traditional signal source (Agilent E4432B) and spectral analyzer (Agilent E4404B), is controlled by the former module and then generates the desired microwave signals.

In above flow, the most important module is the software module, since it constructs the vector baseband signal and directly related to the communication standard.

Baseband signal modelling by ADS: In this stage, we must model the vector baseband signal at the receiver according to the corresponding communication standards.

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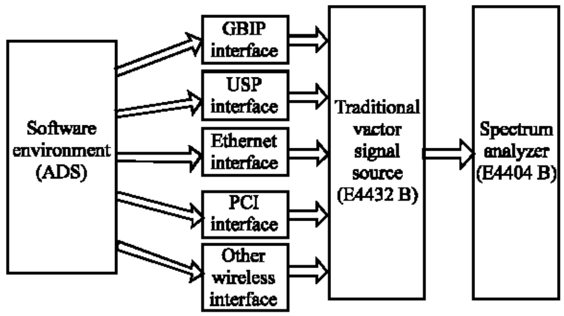

Fig. 1: System diagram of the RF signal source

- Baseband signal modelling at the transmitter, such as TD-SCDMA, WCDMA or any self-defined signal model
- Multipath fading channel modelling, such as Jakes model and directional model
- Additive noise modelling, such as AWGN and impulse noise

The first work can be done as:

- Exploit the existing module of ADS software, such as TD-SCDMA downlink / uplink signal module
- Design the absent module, such as serial-parallel transform
- Set up the global variable list, such as the carrier frequency, the sampling rate, the transmitting power, the pulse shaping filter, the training sequence, the channel Power Delay Profile (PDP), the Signal-to-noise Ratio (SNR) and the frame length

Note that the global variable list also includes the parameters used for the fading channel and the noise and we can change the system output by modifying the variables instead of replacing modules.

The second work must include the following parameters:

- Path attenuation and Angle of Arrival (AOA) mode
- Mobile speed and antenna height
- Path number and PDP

The final work is done real-timely and use the following assumptions:

- Assumes the channel variance is normalized to one
- Noise power is controlled by the pre-defined SNR

Baseband signal verification by MATLAB: MATLAB is effective for numerical computation (Hanselman and Littlefield, 1998; Gilat, 2008) hence, we design a Matlab module to collect the baseband signal generated by ADS and then test them to ensure that the signal is correct. There are two important issues must be taken into consideration:

- Design a data collect module in ADS and collect the baseband data within the time interval 0~N T_s
- Design a frame structure tester in Matlab to verify the collected data according to the communication standard

where, T_s denotes the sampling interval and all collected datas are saved in matlab format. In order to clearly show the design procedure, next we will provide an example on TD-SCDMA microwave signal source design.

APPLICATION IN DESIGNING TD-SCDMA SIGNL SOURCE

TD-CSDMA baseband signal structure: TD-SCDMA protocol specifies the four-layer physical frames (3GPP, 2008): Super-frame, Radio-frame, Sub-frame and Time Slot (TS). A super-frame is of 720 msec duration and includes 72 radio-frames and one radio-frame is subdivided into two sub-frames, where each sub-frame consists of seven main time slots and three special time slots: downlink pilot TS (DwPTS), Guard Period (GP) and uplink pilot TS (UpPTS). In addition, each main TS contains a GP (32 chips) at the end.

In above main TSs, TS0 and TS1 are allocated as downlink and uplink respectively, while other TSs can be allocated as downlink or uplink according to system configuration. Between the two pilot TSs, the GP duration is of 75us (96 chips).

ADS software modeling: The ADS is a powerful design software in wireless and microwave research, since it provides the fully integrated design for most cellular and portable communication systems, wireless networks, radar systems and satellite communication systems.

In present study, we model the TD-SCDMA signal as Fig. 2, where several major modules are exploited, i.e., the original signal module (Downlink TSx and Uplink TSy), the multipath channel module and the AWGN module. In addition, DDC, DUC and filter represent the frequency down converter, the frequency up converter and the Root-Raise-Cosine (RRC) filter, respectively.

The process of Fig. 2 can be explained as:

- Generate the downlink and uplink TSs by the embedded TD-SCDMA baseband module of ADS

- Combine the downlink TSs and then feed them to the multipath and AWGN module
- Feed every uplink TSs to the multipath and AWGN module and then combine them together
- Combine the uplink TSs and the downlink TSs
- Output the combined signals to the E4432B hardware through the embedded E443XB module

Note that we have some global variables to be determined, such as carrier (1900MHZ in present study), midamble number, power, DwPTS sequence and UpPTS sequence. Besides the baseband signal, we exploits the multipath fading channel module in Fig. 3, which is an embedded module of ADS and requires to determine some parameters in advance, such as PDP and mobile speed.

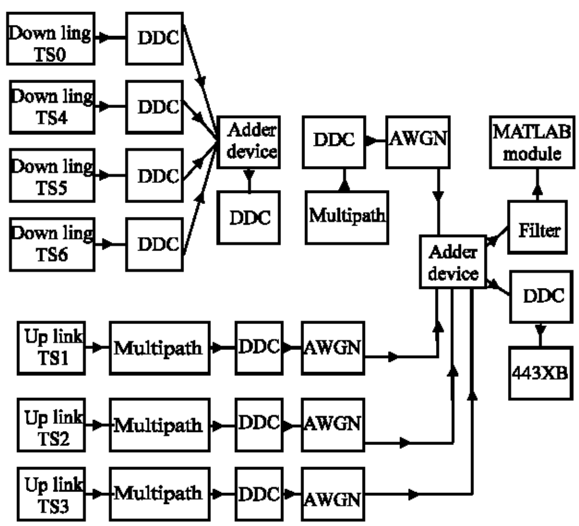

Fig. 2: ADS systematical circuit in our study

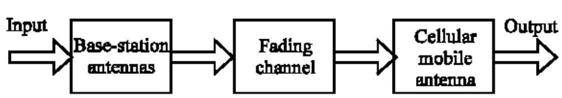

Fig. 3: The multipath channel module

Next, we also design an AWGN module to simulate noise corruptions, which is realized in baseband, thus we should use DUC before this module. The detailed illustration of the AWGN module is shown in Fig. 4.

In Fig. 4, we calculate the average power of transmitted signals and derive the noise power accordingly. Then with the help of a time-clocked control signal, we will maintain this noise power in certain durations and generate noise samples (with a certain power).

After the complete TD-SCDMA baseband signal is produced, two tasks remain. The former is passing the baseband signal through a matched filter and verifying the filter output by Matlab, where the verified results will help us to adjust the system parameters in Fig. 2. The latter is producing the vector microwave signal using the verified parameter setup, which is realized by a DUC component and a 443XB component of ADS, where the DUC outputs are transferred to our E4432B signal source through 443XB and the vector microwave signal can be collected in the output of E4432B.

VERIFICATION OF TD-SCDMA SIGNAL SOURCE

MATLAB verification: First, we verify the outputs neglecting both AWGN and fading channel, where we adopt four times over-sampling and 64-tap RRC filter.

In Fig. 5, we try to verify the DwPTS power and location. Note that DwPTS begins at the 897th sample and ends at the 960th sample in a normal-sampling sub-frame. Hence, given the over-sampling factor and the filtered delay, DwPTS should begin at the 3649th ($896\times4+64+1$) sample and end at the 3901th ($959\times4+64+1$) sample, which is consistent with Fig. 5. Moreover, the adjacent GP of DwPTS is observed, which further approves our signal modeling in ADS software. Besides, as the transmitted DwPTS signal contains a group of Pseudo Noise (PN) sequence ($\{S_k, k = 0,1,..,63\}$), we also use $\{S_k\}$ to match the demodulated DwPTS signal (y(k)) and obtain a consistent results again.

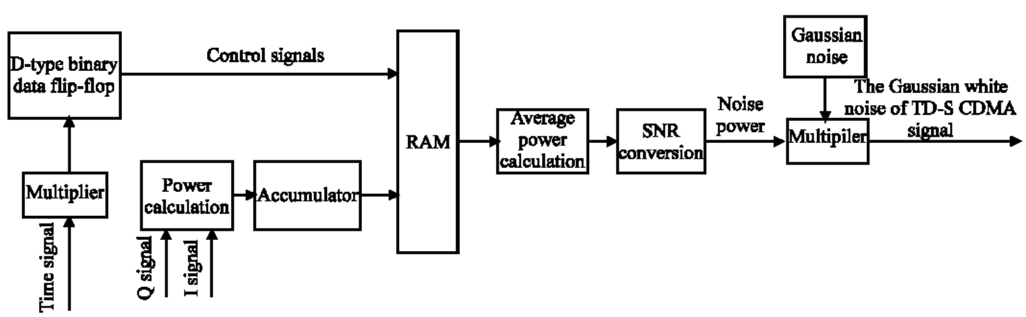

Fig. 4: The AWGN channel module

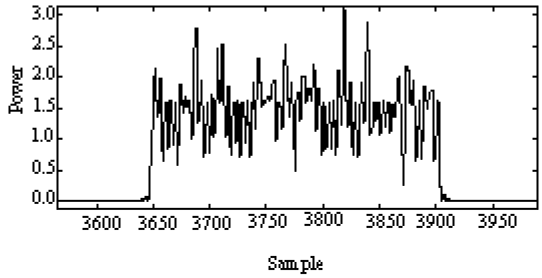

Fig. 5: MATLAB verification without AWGN and fading channels: DwPTS snapshot

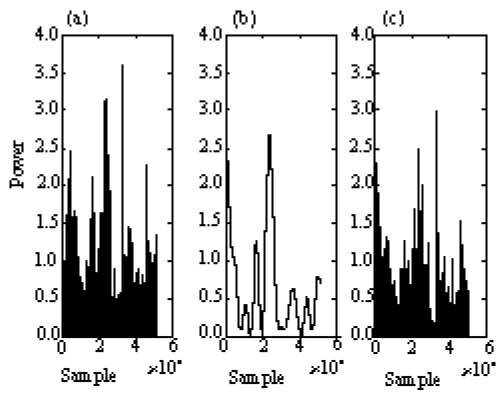

Fig. 6: MATLAB verification with AWGN and fading channels: Power v.s. sample

Now, we have both AWGN and fading channel are taken into consideration.

Figure 6 shows the MATLAB verifications at SNR 3dB, where, Fig. 6a-c derive from the receiving signal level, the downlink channel envelope and the AWGN level, respectively. We explicitly see that the receiving signal level and the channel envelope have the same trend. Moreover, since, SNR is 3dB, the receiving signal power should be approximately three times as large as the AWGN power. Then after computing by Matlab, we find that the receiving signal power is 0.3 mw and the AWGN power is 0.11 mw, which further proves that our design in Fig. 2 works effectively.

Hardware verification: In order to check the physical microwave signals, the first step is to make the ADS software identify the external signal source (ESG E4432B) and then control it to generate the physical microwave signals in the second step. Fortunately, ADS has instrument connecting softwares (CMS: connection manager server) to realize the first step, which is controlled by 443XB module in Fig. 2. Then our E4432B is identified and the second step is accomplished consequently.

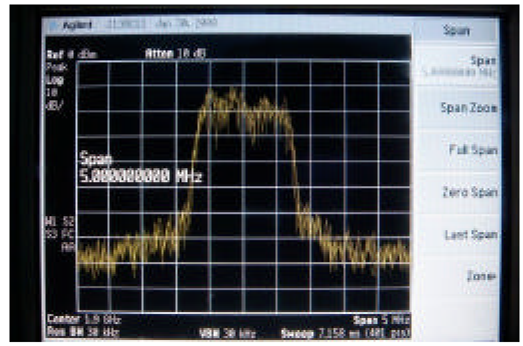

Fig. 7: TD-SCDMA signal tested by Agilent E4404B spectral analyzer

Figure 7 shows the TD-SCDMA microwave signal spectrum in a spectral analyzer (Agilent E4404B), where the total span of the X-axis is 5MHz, with each small grid denoting 500 KHz. From it, we explicitly see that the center frequency is 1.9 GHz and when the spectrum amplitude decreases 3dB, X-axis span is close to 2.5 grids, which means that the bandwidth is nearly 1.28 MHz. These observations match to the TD-SCDMA standard and our setup in ADS software.

CONCLUSION

This study proposes to use ADS software and conventional low-price signal source to model and generate vector microwave signals corrupted by AWGN and fading channels. Then, a TD-SCDMA signal source is designed accordingly and the test results approve the propose method. Moreover, since ADS software can be configured flexible, the proposed method can be applied to design and generate other wireless communication signals easily.

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