Experimental research on MIMO communication based on SDR

Hong Li

Experiment and Practical Training Center of Electronic Information Engineering, Handan University, Handan, 056005, China

Keywords: SDR, MIMO

Abstract: Software radio technology, in short, is a wireless communication protocol based on software definition, which is feasible under the condition of partially changing hardware. Software can be used to realize more functions in limited hardware combination. Its basic idea is to use pure software programming technology to operate hardware circuits, and realize different functions with different programs in a circuit system composed of the same hardware. The software radio technology itself has good openness and operability, and its proposal and development is of great significance to the whole communication field.

1. Introduction

In recent years, with the rapid development of communication technology, especially the rapid advancement of wireless local area network technology and wireless personal area network technology, the contradiction between limited spectrum resources and unlimited application requirements is becoming increasingly acute. People began to seek some solutions to this contradiction. The first thought is to develop new wireless access modulation technologies, such as orthogonal frequency division multiplexing, MIMO (MultipleInputMultipleOutput), relay, cooperative communication and so on. These technologies have improved the utilization rate of spectrum to a certain extent, but compared with the growth rate of people's demand for bandwidth of spectrum resources, they are still far behind [1].

Scholars at home and abroad mainly focus on dynamic resource allocation technology in cognitive radio system based on SDR. The variable rate multi-user SDR system is studied in the literature, and the system model is established under the MA criterion. The optimal solution is obtained by introducing Lagrange operator, and the optimal allocation is realized theoretically. However, the shortcomings are slow convergence, high complexity, and the QOS of cognitive users cannot be guaranteed. The sub-optimal algorithm of allocating subcarriers first and then allocating power is adopted to allocate resources for VDR multi-user SDR system, which comprehensively considers the interference limitation of cognitive users to authorized users and QOS guarantee among cognitive users.

2. OSTBC coding in 2.MIMO-SDR cognitive radio system

2.1. STBC-SDR system

The combination of MIMO and SDR technology makes up for their respective shortcomings, and reflects their advantages in time domain, space domain and frequency domain, which makes the tolerance for noise, interference and multipath in wireless communication system become larger [2]. At the same time, it can be coded by spatial diversity technology of multiple transmitting antennas, thus further improving the transmission rate of the system. This section discusses the representative STBC-SDR system with two transmitting antennas and one receiving antenna. The system block diagram is shown in Figure 1.

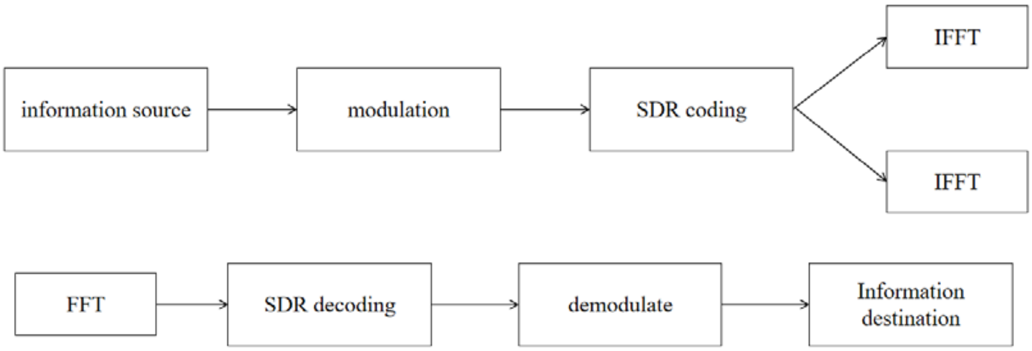

Fig.1 STBC-SDR system block diagram

At time t, the signal passes through the STBC encoder and the output sequence is as follows.

$$c^t = c^t_{1.0}, c^t_{2.0}, c^t_{1.1}, c^t_{2.1} \ldots c^t_{1.l-1}, c^t_{2.l-1} \tag{1}$$

In which I = 1, 2, ... l is the number of SDR subcarriers, and $c^t_{i.k}$ represents the output sequence after modulation, and then the following sequences are modulated by the modulation mode of SDR system:

$$\begin{aligned} &c^t_{1.0}, c^t_{1.1} \ldots c^t_{1.l-1} \\ &c^t_{2.0}, c^t_{2.1} \ldots, c^t_{2.l-1} \end{aligned} \tag{2}$$

The analysis of STBC-SDR system performance is mainly from the point of view of bit error rate. Assuming that the code word symbol transmitted by the transmitting antenna at the transmitting end is C, and the code word received at the receiving end is E, the obtained code word symbol C can be regarded as the paired error of the code word symbol E at the receiving end, and the upper bound of this communication process can be expressed as:

$$P(c \to e | H) \le \exp P\left(\frac{d^2(c,e)E_s}{4N_0}\right) \tag{3}$$

It can be seen that the STBC-SDR system can achieve the maximum diversity gain, which can be shown as $N_T N_R L$, which respectively indicates the number of transmitting antennas, the number of receiving antennas and the number of multipath of frequency selective fading channels, that is, the diversity number [3]. For STBC-SDR system with two transmissions and one reception, it can achieve full diversity gain and realize dual diversity in space domain and time domain.

2.2. STFBC-SDR system

We assume that the channel is quasi-static, but there are two common phenomena in the actual wireless communication channel, one is Doppler frequency shift and the other is multipath fading, which leads to frequency selective fading of the channel. Therefore, SDR system needs to be combined with a new technology based on space, time and frequency, namely Space Time Frequency Blocking (STFBC). STC technology is proposed on the basis of STFBC, which not only considers the diversity in space and time, but also considers the diversity in frequency domain. STC technology is proposed on the basis of STFBC, which not only considers the diversity in space and time, but also considers the diversity in frequency domain. The STFBC-SDR system is roughly the same as the STBC-OTOM system, and the main difference is the codec. It is assumed that Nt, root transmitting antenna and Nr receiving antenna are used in MIM○-SDR system, and the number of subcarriers is set to Yv. It is assumed that the number of symbols on the transmitting antenna I is n, the sequence transmitted on the antenna with the number of subcarriers k is. j (j(j=1 1,2, ⋯Nr), one of the multipath channels at the receiving end is assumed to be l(l=0,1,2,L-1), and the channel excitation is h, so the simulation environment is assumed to be ideally synchronized [4]. After receiving the signal, the terminal performs cyclic prefix removal and FFT transformation. Then, the received signal sequence can be expressed as:

$$j_n^k(k) = \sum_{i=1}^{N1} H_j, i(k) x_n^i(k) + w_n^j(k) \tag{4}$$

Simulation results show that STFBC-SDR system has the highest reliability in the same transmission environment. When the bit error rate is about 10^{-2}, the signal-to-noise ratios of the three systems are 5dB, 8dB and 12dB respectively.

2.3. SDR module

SDR technology is used to combat interference between codewords and multipath fading encountered in the process of channel transmission. Using orthogonal design carriers can greatly improve the spectrum utilization. The basic idea is that a series of data is converted into multiple parallel low-speed data for transmission at the transmitting end, then the converted sub-data stream is orthogonally modulated and loaded on the modulated sub-carrier for fast Fourier transform. Finally, the cyclic prefix is added to the data to be transmitted to resist the mutual interference between code words, and the opposite operation is performed at the receiving end after being transmitted through the wireless channel [5].

SDR technology can dynamically load the data allocated on the sub-carriers involved in the frequency band occupied by the main user to other sub-carriers, and adjust the data rate according to the signal-to-noise ratio of each sub-carrier, that is, realize the function of spectrum clipping. The spectrum sensing module compares the detected spectrum resources with the database, and then allocates subcarriers to the SDR module, but the premise is that the cognitive primary users in the frequency band are not working, that is, the frequency band is idle.

3. Feasibility analysis and simulation results of technology convergence

3.1. The precoding technology based on OSTBC in MIMO-SDR cognitive wireless system

The scheme proposed in this paper combines M1M0, SDR, OSTBC and CR ideas and other adaptive transmission technologies to achieve rational allocation and full utilization of radio resources. Among them, the adaptive transmission technology includes dynamic subcarrier allocation, power control, multi-antenna resource allocation, adaptive modulation and coding, etc., all of which work together to form an optimized adaptive algorithm. According to the signal-to-noise ratio of subcarriers, the base station adaptively adjusts the working parameters of establishing links with communication terminals, so as to achieve the best working state and effectively improve the utilization rate of spectrum resources and the communication performance of the whole system [6].

To sum up, the whole adaptive process is divided into the following three steps:

1) A channel estimation; In the structure of cognitive MIMO system based on OSTBC, the spectrum sensing and channel estimation module estimates SINR of each subcarrier, feeds back the current channel quality in segments, and obtains the current channel estimation information by using blind channel estimation method, semi-blind channel estimation method and channel estimation method based on training sequence according to the bit error rate of the current channel.

2) Channel information feedback; Sub-carrier feedback can reduce feedback overhead and achieve ideal feedback state.

3) Cognition; According to the channel quality and channel estimation information received by the base station, a certain fairness principle is adopted, and according to the specific needs of users, such as data rate, feedback channel information and spatial subchannel gain, the subcarrier with the

best conditions is selected to allocate frequency resources, and then the appropriate modulation, coding and transmission power are selected according to the subcarrier quality, and the antenna configuration and subchannel selection are carried out in combination with MIMO technology. This is a process of constantly perceiving the external environment and dynamically adjusting the parameters according to the changes of the environment, which is the value of the scheme [7].

To verify the feasibility of the scheme, the OSTBC cognitive system is simulated, assuming that the transmission power of all transmitting antennas is the same. in order to better analyze the simulation results, the performance curves of uncoded system and CR system using Alamouti coding are also made as reference. The Alamouti code is modulated by QPSK, while the OSTBC is modulated by 16-QAM. In the simulation process, it is assumed that the attenuation within the symbol remains constant, and the symbol frames are independent of each other.

Fig. 2 shows the BER curve of the system when the number of receiving antennas is 1.

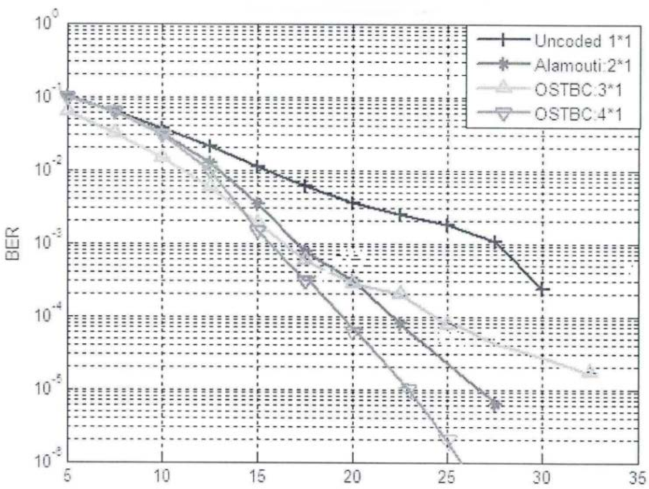

Fig. 2 SNR

The simulation results show that the cognitive system using OSTBC has a significant improvement in BER performance compared with the uncoded and STBC systems. It is worth noting that OSTBC does not limit the number of transmitting antennas, and is more suitable for cognitive radio communication systems than STBC. At the same time, with the increase of the number of receiving antennas, the performance of OSTBC can be improved. The more receiving antennas, the better the performance of OSTBC, because the diversity gain of space-time codes increases with the increase of receiving antennas, which is the main reason why OSTBC is chosen instead of STBC in this paper [8].

3.2. MIMO Precoding technology in system

There are many classification methods for precoding techniques in MIMO systems. For example, according to different application environments, it can be divided into precoding in single-user MIMO system, precoding in multi-user MIMO system and precoding in MIMO cooperative system. According to whether the coding criterion is linear or not, it can be divided into linear precoding and nonlinear precoding. According to the situation that the sender knows the channel information, it can be divided into precoding based on complete channel information and precoding based on partial channel information.

Nonlinear precoding is more complicated than linear precoding. Generally, all users' data are encoded in a sequence. After the first user's data is encoded, the second user eliminates the interference of the first user at the sending end by using the channel state information known by the sending end, which means that all users are jointly encoded [9]. Typical nonlinear precoding includes dirty paper coding and Tomlinson-Harashima precoding.

3.3. Optimal linear precoding design criteria

Through the analysis of the previous chapters, it can be seen that incorporating appropriate space-time coding technology and precoding technology into cognitive system can really improve the performance of the whole system. In this chapter, an extended precoding scheme is proposed on the basis of scholars' research on this subject. Both the main user and cognitive users can use multiple antennas and adopt a multi-carrier transmission scheme. Meanwhile, the correlation between both ends of the receiving and transmitting antennas of cognitive users is also taken into account. The linear precoder designed in this chapter preprocesses the traditional OSTBC to minimize the average paired error probability.

In the uplink direction of communication link, it is necessary to consider the correlation between sending and receiving of cognitive users at the same time. At this time, the multi-antenna access point is located above the multi-antenna subcarrier transmitting unit, and the small scattering range of the receiving antenna leads to a small arrival angle. Therefore, high reception antenna correlation is caused at the receiving end. In the case of multi-antenna subcarrier transmission, the possible causes of transmission correlation are the small distance between antennas, antenna arrangement and antenna configuration, etc.

4. Conclusions

There are still many problems worthy of further discussion whether it is OSTBC coding or cognitive radio technology. In the research process of OSTBC coding technology in cognitive MIMO-SDR system, this paper takes bit error rate as the basis for performance comparison. With the continuous growth of wireless communication services, high security is no longer the only requirement. Therefore, factors such as channel capacity and transmission rate can be taken into account to comprehensively compare OSTBC performance under various conditions. This paper only studies OSTBC coding in cognitive system, and there are many types of space-time coding, such as space-time trellis coding and quasi-orthogonal space-time block coding, etc. Whether they can be applied in cognitive system is worth exploring. With the increasing transmission rate of communication system, the number of subcarriers in SDR system becomes larger and larger, which requires high complexity of bit allocation algorithm for modulation among subcarriers. The channels in cognitive systems are usually time-varying, and the previous modulation algorithms with heavy computation and slow iteration speed are no longer suitable. It is necessary to further study the structure and idea of the new modulation algorithm in order to improve the performance of the whole cognitive system. In a word, cognitive M1MO-SDR system is a challenging but significant research field. How to integrate cognitive technology with other key technologies in the 4th generation mobile communication system will surely gain more extensive attention and further development.

References

[1] Chen Yu, Yang Jundong. Experimental research on MIMO communication using software defined radio (SDR) [J]. Electronic testing, 2020, No. 434 (05): 83 + 87-89

[2] Zhang Mengjiao, Gao Junhui, Cao fan, et al. Hardware realizable channel estimation algorithm in high-order MIMO system [J]. Wireless communication, 2017, 7 (2): 8

[3] Deng Huming. Design of a multi-channel software radio platform with zero if Architecture [J]. Electronic quality, 2020 (8): 47-53

[4] Ru Minghua. Simulation and implementation of software radio receiver [J]. Information technology and informatization, 2018, 000 (007): 41-43

[5] Wu Qingguo, Zang Jiankun. DSP Implementation of complex filtering SSB in software radio [J]. Journal of Shanxi Datong University (NATURAL SCIENCE EDITION), 2018, V.34; No.168(01):19-23.

[6] Bai Chunlei. A new software radio software architecture with high real time, low cost and waveform sharing across hardware platforms [J]. Electronic technology and software engineering,

2018, No. 134 (12): 53-57

[7] Cheng Sheng. Research and Discussion on the implementation scheme of maximum download rate of DLCA (downlink CA) based on sdm850 platform -- 4CA + 4 * 4mimo implementation scheme [J]. Computer fan, 2018, 000 (026): 250-251

[8] D Günther, Leupers R, Ascheid G. Efficiency Enablers of Lightweight SDR for MIMO Baseband Processing[J]. IEEE Transactions on Very Large Scale Integration Systems, 2016, 24(2):567-577.