A New Type Multi-Function Ionospheric Sounding System

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Abstract

This paper introduces a new type Multi-Function Ionospheric Sounding System (MFISS), which bases on the PXI bus. The capabilities of ionospheric vertical sounding, ionospheric oblique sounding and ionospheric oblique backscattering sounding were integrated in a single MFISS, it overcomes the disadvantages of the original ionospheric sounding equipments which have the feature with less function, limited coverage, less obtaining parameters, it also can achieve the function of acquiring the omnibearing geophysical characteristics, the ionosphere channel propagation characteristics and the radio environment characteristics. In this article, firstly, the system structure and the flow of signal processing were introduced, then some typical sounding results acquired by different detection modes were displayed. The sounding results indicate that the system is equipped to handle fast and has a high degree of software features, so for Engineering applications. it is of great significance for the development of ionospheric detection technology and the study of High Frequency(HF) channel characteristic.

1. Introduction

As the most of the traditional ionospheric sounding devices[1] could only realize a single detection mode, building up an multi-function ionospheric sounding system would be able to overcome the disadvantages of the original ionospheric sounding equipments which have the feature with less function, limited coverage, less obtaining parameters, it also can achieve the function of acquiring the omnibearing geophysical characteristics, the ionosphere channel propagation characteristics and the radio environment characteristics.

The Multi-Function Ionospheric Sounding System, (MFISS)developed by Wuhan University Ionosphere Laboratory[2], is a kind of HF high frequency digital over-the-horizon radar, which is used for high-precision measurement of the ionosphere multipath spread, Doppler frequency shift and spread, and phase fluctuations of information[3,4,5]. This system is based on phase modulated pulse compression[6], because of a long modulated pulse and pulse compression coding technology, the sensitivity of the MFISS was greatly improved. With a higher range resolution, MFISS is of practical significance for studying the fine structure of the ionosphere and carries out a long-distance detection under the low-power conditions. Being based on PXI Bus[7], The whole system is of great advantages of low power, high precision detection, high detection speed, small size, high software degree and high universality.

2. DESCRIPTION OF MFISS
2.1 Configuration

Fig.1 shows a block diagram of MFISS system. The hardware architecture of MFISS is divided into three parts: Transmit channel, receive channel and the GPS time and frequency synchronization module. All modules are based on PXI bus, and be inserted into the PXI bus mainframe for favorable electromagnetic compatibility and maneuverability. Transmit channel consists of an arbitrary waveform generator (AWG) and an power amplifier. AWG is responsible for generating all required code modulation waveform, various modulation waveform generated by AWG acrosses through feeder cables to amplifier unit to radiate out through the antenna; Receive channel is mainly responsible for the echoes demodulation and processing, in order to obtain the final parameters of the ionosphere;and the main function of Time and frequency synchronization module is to use GPS signals for time and frequency synchronization, because of the complement of ionospheric oblique measurement[8].

2.2 System design
2.2.1 Time and Frequency Synchronization Module

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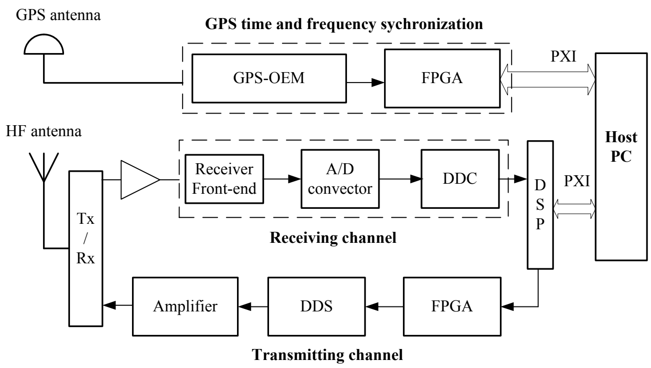

Fig. 1. Block diagram of the MFISS system.

As mentioned above, MFISS has the ability of oblique sounding, in order to achieve the capabilities; two MFISS should be placed several kilometers away. The principle of oblique detection is: the transmitting channel of local MFISS emits the radio wave, through the reflection of ionosphere, the radio wave is gained by the receiving channel of another MFISS which is at remote place, demodulation processing and analysis will gain the radio group delay and Doppler information during propagation in order to acquire the state of the ionosphere [9]. In order to get the precise information above, a strict time synchronization and frequency synchronization features must be ensured between the transmitter and receiver. For the time synchronization, 1PPS signal which is generated from GPS receiver can ensure the accuracy, and we use the rising edge of the 1PPS signal to synchronize the work time of transmitter and receiver at different places; For the frequency synchronization, we use the 1PPS signal to train the local clock, which makes the transmitting and receiving own the same clock frequency. The consistency of time and frequency can guarantee the accuracy of the signal group delay and Doppler information which acquired by ionospheric oblique detection.

GPS module acquires and demodulates the satellites' signals, then outputs the data stream for external equipments' acquisition and processing; 1PPS signal was generated by the atomic clock oscillator on GPS satellites, so that the local VCO output clock can be consistent with satellites clock while using the precise 1PPS to train it. Cycle adjustment unit uses the 1PPS signal as a standard clock and generates the count trigger signal according to the count cycle value-K. Counter module counts the VCO output clock(e.g.10MHz±10Hz, ± 10Hz as the maximum VCO tuning range), and inputs the results into the frequency calibration analysis unit. This unit analyzes the count results and compute the values of frequency deviation and count period, and outputs the values to digital adjustment unit and cycle adjustment unit; Digital adjustment unit calculates a corresponding value to control DAC output DC level for calibrating VCO output frequency. The stability of local VCO clock is guaranteed by the 1PPS signal, the accuracy depends on the adjustment cycle value k, the feedback loop output frequency accuracy is 0.001Hz after it is stable, that is to say the local clock is synchronized with satellites' clock.

2.2.2 HF Tranceiver

This HF tranceiver is a high performance multi-mode digital signal processing tranceiver with a frequency range from 3 MHz to 30 MHz. It is designed as a PXI message-based interface module, and adopts double super heterodyne principle with two conversion stages, the IF digitization architecture, thought of software defined radio.

In the transmitting end, the generation of the modulated signal is accomplished by the quadrature digital up-converter AD9857[12]. It accepts the frequency word from the controlling module through SPI interface, and generates the RF signal. At the same time, it accepts the amplitude and phase modulation signal from FPGA to modulate the RF signal which is appropriately amplified and sent to a high power amplifier for transmitting.

In the receiving end, a Tx/Rx switch component was equipped for receiving timing control and as the input overload protection circuit for the following components. The incoming RF signal bandwidth is limited to 3MHz-30MHz by a seventh order lowpass filter and a high pass filter to reject image frequencies, intermediate frequencies, and the oscillator reradiation. The preselector filter banks then follows, it assembly consists of seven bandpass filters. In order to improve the selectivity of the receiver, an about 6dB gain amplifier controlled by the switchers is introduced. A discrete assembly high level switched FET mixer used to mix the filtered RF signal with the output of the first local oscillator (LO1). The LO1 tuning range is 44.4 to 71.4 MHz. For the first IF conditioning, three low insertion loss crystal bandpass filters providing a bandwidth of 30 kHz at 41.4 MHz are used. Using the LO2(40MHz), the second mixer performs a down conversion of the band limited signal to the second IF of 1.4 MHz. The mixer output is passed through a first order lowpass filter to suppress image frequencies and then amplified for AD converting.

2.2.3 Signal Processing Procedure

After AD sampling, the digital IF signal is converted to the zero IF. Considering the high sampling rate, a special digit down converter (DDC) processor – AD6620 of the Analog Device Corporation[10], is used to accomplish this function. It can extract the requiring narrowband signal from the input broadband signal, convert the signal to baseband signal in the digital I&Q channels, and output the signal in many kinds of format. The AD6620 includes various digital programmable filters(CIC and FIR filters), whose parameters can be adjusted to achieve the function of frequency converting and matching filtering. After that, the baseband signal is accepted by a fixed-point digital signal processor(TMS320C6205 of TI Corporation) [11]and FPGA.

DDC decimates and filters the high sampling rate data and outputs the low-rate I and Q data streams. DSP collects them and completes the Digital Pulse Compression and FFT processing[13], the processing results stores in the external memory space, and then DSP notices PC host to remove the data through high-speed PXI Bus for showing the Echo Information on the PC screen.

TMS320C6205 chip provides a wide range of integrated peripherals, and the 32 bit / 33 MHz PCI master/ slave mode interface which can be seamlessly access with the PC host. In the computer program, WinDriver software was provided as a driver development platform and VC + + was the development environment, relying on the two software, the communication procedures were developed. PC took over all the control of DSP through PXI Bus.

Refer to the DSP&FPGA communications module, DSP communicates with FPGA through asynchronous EMIF interface. A high degree of programmable DSP- FPGA hardware architecture allows the system have wonderful control and processing functions. On the one hand, by controlling the FPGA, DSP can generate the control timing for digital down converter and front-end analog circuits; On the other hand, both as the main control unit, DSP&FPGA can generate the final modulated RF outputs with many kinds of waveform. This makes waveform generator be a flexible mechanism, and the system's anti-jamming performance and programmable level improved.

2.3 System sounding results

An original backscatter ionogram measured at 17:04 LT on March 24, 2009 is shown in Fig.5. This ionogram clearly depicts the distribution of backscattered power as a function of group range and frequency in the range of 2500 kilometers. The variation of the range of the leading edge of the ionogram with frequency is typical of F-layer propagation.

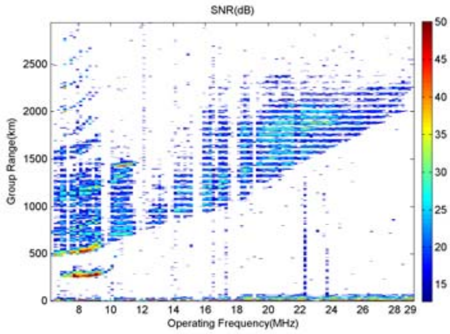

Fig.5. Backscatter ionogram of MFISS. The operating frequencies are set between 6.2MHz and 29.2MHz, the swept-frequency step is 200 kHz,the average transmitting power is 200W.

An original oblique ionogram measured at 15:15 LT on March 28, 2009 is shown in Fig.6 for propagation over a distance of more just over 1300km from Wuhan, Hubei to Wanning, Hainan. During this experiment, a single log-periodic antenna at the receiver site is used to receive the oblique-incidence transmissions. This ionogram clearly depicts the E-layer mode, F1 mode, F2 mode and a two-hop mode propagation.

An original Vertical sounding ionogram measured at 9:00 LT on March 26, 2009 is shown in Fig.7. During this experiment, a single whip antenna was used for detection, and the sounding parameters we used as Fig.5, but the transmitting peak power is only 80W. This ionogram clearly depicts the Es-layer mode, F1 mode, F2 mode and a two-hop mode propagation.

3 conclusions

For the character of ionospheric integrated sounding, a new kind of general, modularized, software-based ionosonde which based on PXI bus is designed with technology of software radio. Experimental results demonstrate that this system can satisfy the demands of many ionospheric sounding mode preferably at present. Moreover, because

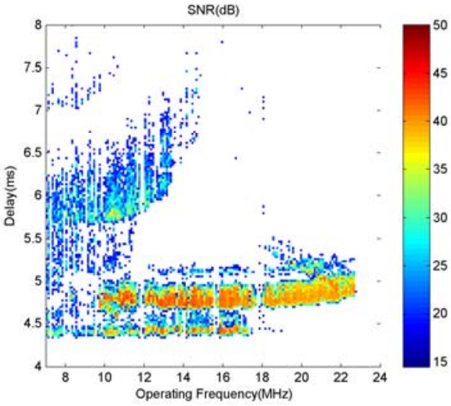

Fig.6. Oblique ionogram of MFISS. The operating frequencies are set between 7MHz and 24MHz, the swept-frequency step is 100 kHz, the average transmitting power is 200W.

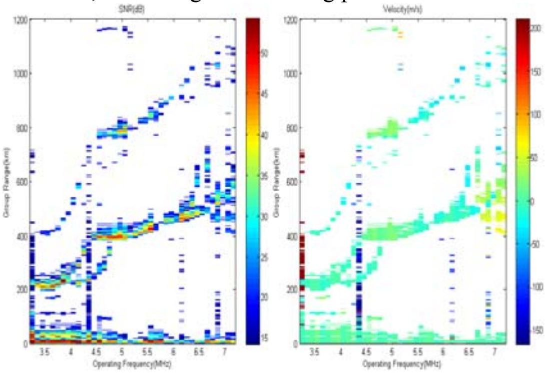

Fig. 7. Vertical ionogram of MFISS. The operating frequencies are between 3MHz and7.5MHz, the swept-frequency step is 100 Hz.

of its good characteristic of multifunctional, flexible, easy upgrading, etc, using this system, different sounding aims and sounding demands can be met by only make a little change on the system's software. So, MFISS is demonstrating its worth as a valuable tool for adopt in HF channel research, associated studies of the ionosphere, various science research of Ionosphere can be realized with this system, and it will promote continuous development of ionospheric detection techniques.

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