UHF Band High-Speed CP-2FSK Modulator’s Design

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Abstract. Aimed at requirements of signal transmission rate in the UAV data link, the UHF band CP-2FSK modulator design method based on Direct Digital Synthesis technology is given, and hardware circuit implementation of the UHF band CP-2FSK functions, get UHF band modulation signal CP-2FSK of code rate up to 67.2 Mbps baseband signal. The transmission experiments of the image signal in UAV data link had been achieved. It suggested the modulator has many advantages such as low power consumption, high output frequency, high transmission rate, occupied channel bandwidth. It meets the design requirements of the UAV data link telemetry data transmission and achieve high-speed transmission UAV telemetry data downlink.

Introduction

CP-2FSK modulation technology with good anti-noise performance and anti-fading performance, and easy achievement, simple demodulate equipments and so on characteristics, widely using in the wireless communication.

At the present, the intermediate frequency of output frequency of the domestic UAV data link is 70MHz. There is a question that low IF limits the transmission bandwidth of the channel. Therefore, it need be improved which is the high frequency and high-speed digital modulator. It can increase the channel bandwidth, transmission rate and realization high-speed transmission of UAV telemetry data.

The UHF Band CP-2FSK Modulator’s Design

The downlink function of UAV data link is to transmit the video signal and the telemetry data of digital multiplexer data [1], which through a channel to the Ground Data Terminal, to complete airborne telemetry data returns and video signal transmission. Digital multiplex data code rate is up to Mbps with CP-2FSK modulation. Considering the system error rate and bandwidth efficiency, the CP-2FSK modulate index is 0.715.

The CP-2FSK modulate index $h$ is

$$h = \frac{(2\Delta f)}{R}. \quad (1)$$

Where:
- $\Delta f$: The frequency deviation, units for MHz;
- $R$: The rate band data, units for Mbps.

UHF (Ultra High Frequency) band CP-2FSK modulator block diagram is shown in Fig. 1. The mode of DDS chip AD9957 is set at Single Tone mode, RS-485 format digital multiplexer data through RS-485 receiver output CMOS Level to the pin 54 of chip AD9957. AD9957 is automatic select Profile0 Register, and Profile1 Register, which accord to the pin 54 of CMOS-level “0” or “1”.

Reference Source Design

The frequency of TCXO is selected 20 MHz, with 3.3V power supply. TCXO output signal is converted to differential PECL signal by differential PECL translator, to the effect that improving system Electro Magnetic Compatibility. According to the literature [3], we can see that improving the system clock can increase the output signal-noise ratio, and improving the output signal of...
Spurious-Free Dynamic Range, so the internal clock frequency multiplier of AD9957 is used, after 49 multiplier frequency, we can get the system clock with 980 MHz.

![Figure 1. UHF Band CP-2FSK modulator block diagram.](image)

**MCU Communication with the AD9957**

MCU and AD9957 device with two-wire serial communication mode write its internal registers. The use of serial interface communication can reduce PCB route, improve the EMC of the modulator. RS-232 transceiver can transform RS-232 level format telecontrol instruction to level format compatible with MCU, and then MCU reconfiguration AD9957 Profile registers, according to have been received telecontrol instruction.

**IF Filter Design**

Finally output signal of DDS chip AD9957 is converted by the DAC. From the literature [3], we can see DDS through the DAC output image frequency and the theoretical magnitude (dBc) of any desired image frequency relative to \( f_{out} \) for:

\[
f = m f_c \pm f_{out} \quad (m=0, \pm 1, \pm 2, \ldots)
\]

The output signal center frequency of the CP-2FSK modulator is 350 MHz. By type (2), we can see the signal pre-filtering contains a lot of image frequency, which are combined of the DAC sample rate (980 MHz) and the desired output frequency (350 MHz), its spectrum within 0 ~ 7000 MHz is shown in Fig. 2.

![Figure 2. Pre-filtering the output signal spectrum of AD9957.](image)

From Fig. 2, we can know that the image frequency has a larger power, so we must use a filter to restrain the image frequency and it can ensure the desired the spectrum purity of output frequency. In Fig.2, the results show that image frequency \( f_c - f_{out} \) (630) MHz has a maximum power which the image rejection is 4 dBc; In the frequency 2GHz ~ 6GHz, the image rejection is greater than 30 dBc. Above 6 GHz, the image rejection is greater than 50 dBc. Usually, the desired image rejection is more than 50 dBc and in Fig.1, the IF filter inhibition in the frequency 630 MHz and 2 GHz to 6 GHz range is more than 46 dBc, 20 dBc.

According to the DDS output signal spectrum and the system requirements for spurious, we select two low-pass filters (LFCN-320) of MINI which is LTCC type. They are used in cascade style and a 3 dB \( \pi \) type resistance attenuator network is inserted between two filters to isolate.
Software Design

There are two code rates of encoded telemetry data. The first telemetry code rate is 8.4 Mbps, and the data frame contains the content of video information and single telemetry data. The second telemetry code rate is the 67.2 Mbps, and the data frame only contains the content of video information and single telemetry data and other.

The FTW is a decimal number of AD9957 Frequency Tuning Word for Profile Register. The value of the FTW is determined by

\[ FTW = \text{round} \left( f_{\text{out}} \times 2^N / \text{SYSCLK} \right). \]  \hspace{1cm} (3)

Where:
- \( N \): The phase accumulator resolution, there is 32;
- \( f_{\text{out}} \): The desired output frequency, units for MHz;
- \( \text{SYSCLK} \): DDS system clock, units for MHz;
- \( \text{Round} () \): Function means to round the result to the nearest integer.

When the baseband data bit rate is 8.4 Mbps and the center frequency of output signal is 350 MHz, according to the formula (1), we can get two CP-2FSK modulation frequencies. They are 347 MHz and 353 MHz respectively. From the formula (3), the results of Profile0 Registers and Profile1 Registers are 5AA51808 and 5C3655AE respectively. When Baseband data bit rate is 67.2 Mbps, the two frequencies are respectively 322 MHz and 374 MHz and the results of Profile0 Registers and Profile1 Registers are 5528C043 and 61B2AD74 respectively.

UART Instruction Protocol

MCU receives telecontrol instruction with UART interrupt mode, and accords to the data type change AD9957 registers of Frequency Tuning Word for Profile Register to ensure whether telemetry code rate at 8.4 Mbps or 67.2 Mbps, UHF CP-2FSK modulation index is always 0.715. The code rate switch UART instruction protocols see Table 1.

Table 1. Demodulation Analysis Results.

<table>
<thead>
<tr>
<th>Frame Header Data Type</th>
<th>Control Word</th>
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<tbody>
<tr>
<td>FE, 90</td>
<td>C1</td>
</tr>
<tr>
<td></td>
<td>D1 or D2</td>
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</tbody>
</table>

When the received instructions are hexadecimal “FE 90 C1 D1”, the telemetry data code rate is 8.4 Mbps. The index is 0.715, from equation (1) can calculate the two CP-2FSK frequency points of modulation, which are 347 MHz and 353 MHz. When the received instructions are hexadecimal “FE 90 C1 D2”, the telemetry data code rate is 67.2 Mbps, setting the AD9957’s the Frequency Tuning Word of Profile0 Register and Profile1 Register respectively correspond to the frequency of 322 MHz, 374 MHz.
Realization of the Program

In the modulator, program flow chart of the MCU is shown in Fig. 3. After power to the MCU, first initialize MCU, AD9957, and then enable the MCU enter the sleep mode, and waiting for UART interrupt. When the serial data is received, MCU immediately enter the interrupt services. In the first place determine whether the first byte is equal with “FE”, if it is equivalent to “FE”, then judge whether the second byte is equal with “90”, otherwise exit interrupt service to enter the sleep mode wait for the next interrupt. And so, after received the first three bytes “FE”, “90”, “C1”, receiving the fourth byte, the fourth byte is judged “D1” or “D2”, and according to the UART instruction protocol reconfiguration AD9957 Profile0 and Profile1 registers.

The Experimental Results

In Fig. 4, the CP-2FSK modulation spectrum of 8.4 Mbps telemetry multiplexing data is shown, and its 3dB bandwidth is 9MHz. In Fig. 5, the CP-2FSK modulation spectrum of 67.2 Mbps telemetry multiplexing data is shown, and its 3dB bandwidth is 70MHz.

Conclusions

From the application experiments, the CP-2FSK modulator which is made up of AD9957 has many advantages such as low power consumption, high output frequency, high transmission rate, occupied channel bandwidth and improve the results in literature [4, 5].

Reference


