THE DESIGN OF C/A CODE GLONASS RECEIVER

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ABSTRACT

GLONASS is similar to GPS in many aspects such as system configuration, navigation mechanism, signal structure, etc.. There exists the possibility of receiving and processing GLONASS signals with GPS technology. The frequency plan of the GLONASS system is different from that of GPS. This makes the front-end of GLONASS receiver more complicated. The work here manifests our initial effort in GLONASS receiving. A design scheme is proposed of a C/A code GLONASS receiver.

KEYWORDS

GLONASS, C/A code, receiver, FDMA, PLL, tracking

INTRODUCTION

GLONASS (GLobal Orbiting NAvigation Satellite System) is USSR's second-generation satellite navigation system. Like GPS, it provides an information service on position, velocity, and time worldwide.

The fully deployed GLONASS system consists of 24 satellites in three circular orbits, at a height of 19100km. The inclination of the orbits is 64.8°. The GLONASS system achieved full operation at the end of 1995[1]. Now its three orbits are filled with more than 24 satellites.

GLONASS is a pseudo-ranging system like GPS[2]. Each satellite emits signals at two frequencies, L1 and L2, in the L-band of the radio-frequency spectrum. These signals are modulated by two binary pseudo-random (PRN) codes, C/A (Clear Acquisition) code and P (Precise) code, and by binary data. The C/A code is transmitted only on L1 carrier for civil uses. The P code is present on both L1 and L2 carriers and is intended to be used by military and authorized users.

Frequency Division Multiple Access (FDMA) is used to separate satellite signals. So there are totally 48 carriers for 24 satellites. The frequencies are:

f_{L1} = (1602 + k · 9/16) MHz,

f_{L2} = (1246 + k · 7/16) MHz,   where

k = 1,2,…,24 - are channel numbers.

GLONASS carrier frequencies are now being shifted downwards from their original values, since in 1992, part of L band, including some of the GLONASS frequencies, was allocated to other international uses. Three steps are to be taken to avoid frequency overlay and interference problems:

- by the year 1998, channels k = (15…21) will be put out of use;
- by 2005, only channels k = (0…13) are to be adopted;
- after 2005, channels k = (-7…6) are to be used with k = 5 and k = 6 for technical channels.

The total channel number will become 12. Two satellites in antipodal position will send signals at the same frequencies.

COMPARISON OF GLONASS AND GPS

GLONASS was set up following the building of GPS. Similarities exist between the two systems. For example, the number and height of the satellites in space, the frequency band at which the satellites send their signals, and the positioning mechanism adopted, are all nearly the same. The table below gives the comparison of system characteristics of GLONASS and GPS.

The signal division method of the two systems is quite different. GPS adopted Code Division Multiple Address (CDMA). Each satellite uses a unique PRN code, but all satellites transmit at the same frequencies. In GLONASS system, FDMA does not require special code modulation to distinguish satellites, so all satellites transmit on the same code. This feature makes the GLONASS and GPS receivers have some difference in their front-end parts.

TABLE 1. COMPARISON OF GLONASS AND GPS NOMINAL CHARACTERISTICS

Parameter	GLONASS	GPS
Satellite number	21+3spares	21+3spares
Orbit number	3	6
Orbit inclination	64.8°	53°
Orbit altitude	19100km	20180km
Revolution period	11h15min	12h
Carrier frequencies(L1) (L2)	1602.5625-1615.5MHz 1246.4375-1256.5MHz	1575.42MHz 1227.60MHz
Modulation code	C/A, P	C/A, P
Signaling	SS/BPSK	SS/BPSK
Multiple Access	FDMA	CDMA
Power level(Minimum)	-161dBw	-160dBw
Code rate (C/A)	0.511MHz	1.023MHz
Code rate (P)	5.11MHz	10.23MHz

BASIC STRUCTURE OF GLONASS RECEIVER

A C/A code receiver only processes the L1 signal. The general structure of a GLONASS multi-channel C/A receiver can be expressed as follows[3]:

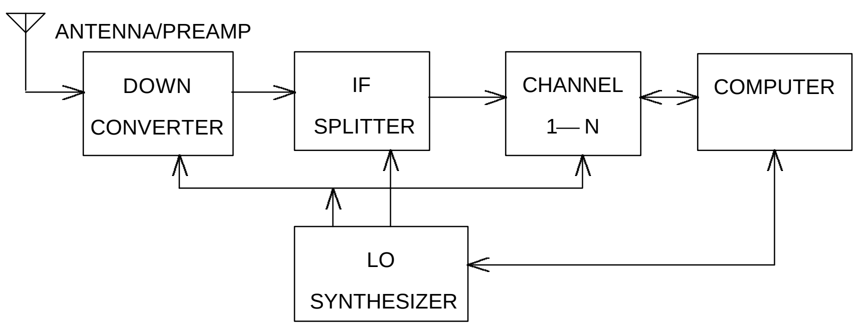

Figure 1. Structure of C /A Code GLONASS Receiver

The Antenna/preamplifier assembly collects and amplifies weak GLONASS signals received from the air. The Down-converter transforms the RF signals to IF band by grades of mixing. The function of the IF Splitter is to separate IF signals of different frequency channels. The LO (Local Oscillator) Synthesizer generates all LO signals needed in the receiver.

The Channel is the most sophisticated part in the whole receiver since the major tracking task is done in it. One typical channel should include: A/D converter, carrier Phase-Locked Loop (Costas PLL), PRN code PLL (Delay PLL), and C/A code generator. When the two PLLs are locked and are in the tracking state, the carrier, the code and the satellite message data can be extracted. The C/A code generator duplicates the GLONASS C/A pseudo-code for code tracking.

The above receiver structure is similar to that of a GPS C/A code receiver[3]. The differences lie in: firstly, because the carrier frequencies of GPS and GLONASS are different, the synthesized LO signals are different too. And GLONASS has multiple carriers while GPS has a single one. This make the synthesizer of the GLONASS receiver much more complicated. Secondly, the GPS receiver doesn't needs the IF splitter. Lastly, the C/A code generator produces only one C/A code in the GLONASS case.

In spite of the differences mentioned above, most of the functional parts of the two receivers are the same. We thought of the possibility of making GLONASS receiver with the GPS components. Now there are the front-end chip and correlator chip that can accomplish the signal tracking and extracting in the market, for example, GP2010 and GP2021. The functions provided by these chips are to be introduced before the design is discussed.

GPS CHIPSET INTRODUCTION

GP2010 is an RF front-end for GPS receivers. It contains a PLL frequency synthesizer, three stages of mixers, AGC amplifiers and an A/D converter, as shown in Figure 2.

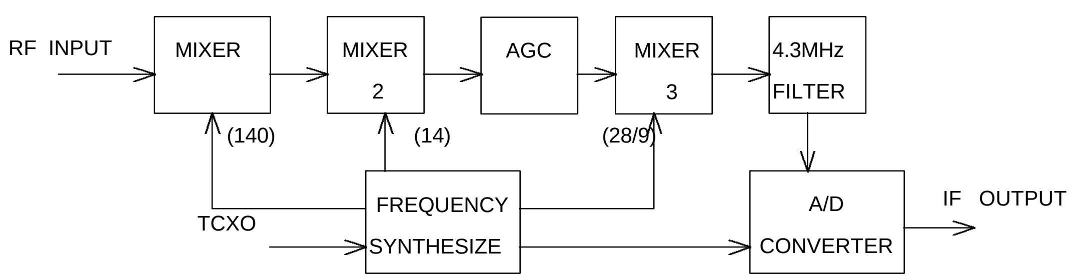

Figure 2. Structure of GP2010 Front-end

The frequency synthesizer is achieved by implementing a PLL for stability considerations. It produces three LO frequencies used for GPS down-conversion, which are 140, 14, and 28/9 times of 10MHz frequency (the normal input clock signal to the chip) respectively. Down conversion is accomplished in the mixers. The input RF GPS signal is subtracted by three LO frequencies generating the IF output. The on-chip filter has a bandwidth of 2MHz. It is designed to allow GPS C/A code to pass through. This chip converts analog RF signals buried in the noise to an IF digital signal of high S/N ratio.

GP2021 is GPS's correlator chip. It consists of 12 channels of tracking modules and interfaces to the micro-computer. Each tracking module is independent and includes the following parts: Costas PLL, Delay PLL, C/A code generator, and accumulators and counters for data recording. One correlator can be connected directly with one or two front-end chips. Figure 3. gives the block diagram of one channel of the correlator.

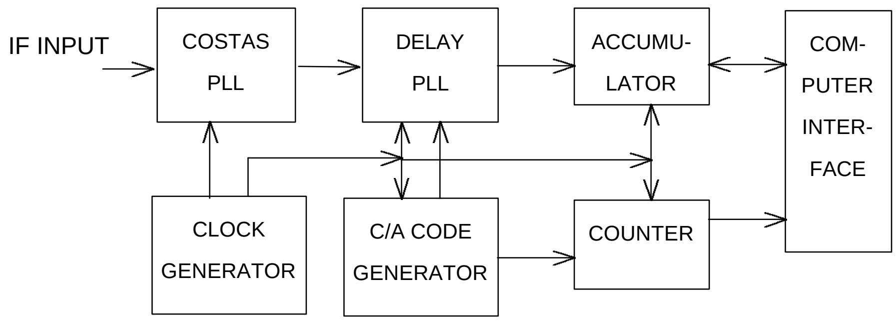

Figure 3. Block Diagram of GP2021 Correlator

DESIGN OF GLONASS RECEIVER

Comparing the structure of the two chips (Figures 2. and 3.) with the diagram of the GLONASS receiver (Figure 1.), we can concluded that this GPS chipset is capable of constructing the GLONASS receiver. The reasons are:

1. Because the radiating power and frequencies of the GPS and GLONASS systems are very close(see Table 1.), the chip GP2010 may be used as a GLONASS front-end to achieve down conversion and A/D conversion.
2. The C/A code generator of the correlator can be programmed to generate GLONASS C/A code. The LO frequency of the Costas PLL can be set in each channel and has very fine resolution, which enables the altering of the LO in the GLONASS case. So each channel can be set up for GLONASS.
3. The IF splitter doesn't need additional components to realize. The separation of IF GLONASS signals occurs when the demodulation in the Costas PLL is performed.

So to construct the receiver, the front-end and the correlator can be connected directly. But due to the difference of GPS and GLONASS, some corrections must be made.

From above section, we know GP2010 provides three stages of mixers and an on-chip filter. After mixing, the GPS RF signal is downconverted to the central frequency of the filter. That is:

$$1575.42\text{MHz} - 140 \cdot 10\text{MHz} - 14 \cdot 10\text{MHz} - (28/9) \cdot 10\text{MHz} = f_o \approx 4.3\text{ MHz} \qquad (1)$$

But when GLONASS signals are input to the front-end, the frequencies of the IF signals will deviate from f_o. To solve this problem, we decide to alter the input clock frequency to the front-end chip. The on-chip frequency synthesizer generates signals according to a certain frequency relation. When the input frequency changes, the output frequency is changed by the same times. This inherent frequency relation of the chip can be expressed by:

$$f_{in} - 140 \cdot x - 14 \cdot x - (28/9) \cdot x = f_o \qquad (2)$$

x is the appropriate clock input to the front-end. Now consider the GLONASS case. The input frequency is f_{glo}:

$$f_{glo} - 140 \cdot x - 14 \cdot x - (28/9) \cdot x = f_o \qquad (3)$$

From equations (1) and (3), in order to locate the IF signal at f_o, the clock frequency should be set as:

$$x = [\, 9 \cdot (f_{glo} - 1575.42) + 14140 \,] / 1414 = 10 + 9 \cdot (f_{glo} - 1575.42) / 1414 \ \ (\text{MHz}) \qquad (4)$$

Because the electric characteristics of the circuit components, x should not be changed too far away from its normal value. When f_{glo} takes on the lower or upper frequency limit, which is 1602.5625MHz or 1615.5MHz, x should be 10.172760MHz or 10.255106MHz. These values are all near the normal 10MHz frequency. Because the GLONASS carrier frequencies are equally-spaced , the input x values have equal intervals too. These frequency values can be easily generated with an external PLL frequency synthesizer.

The GP2010 front-end has a bandwidth of 2MHz, which allows 3 adjacent channels of GLONASS L1 signals to pass through. That is :

$$0.5625 \cdot (3 - 1) + 2 \cdot 0.511 = 2.147\text{MHz} \approx 2\text{MHz} \qquad (5)$$

A front-end thus can receive three GLONASS signals simultaneously. The middle signal is located at f_o.

With two GPS front-ends connected to one correlator, the GLONASS receiver of six channels is easily achieved, as shown in Figure 4.

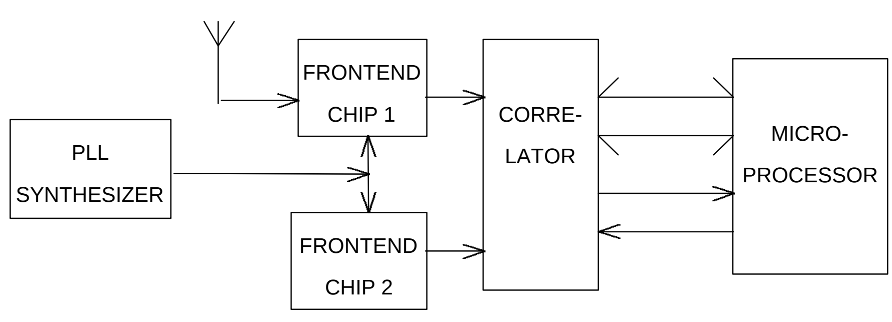

Figure 4. 6-channel C/A code GLONASS receiver

The TMS320 processor undertakes most of the navigational data processing work which requires fast computing. The software is compiled in C language.

DISCUSSIONS

Because the building of the designed GLONASS receiver is still going on, no tracking observation and computing results can be obtained. Only the design idea is presented in the paper.

There are two methods at present to realize a GLONASS receiver — digital hopping scheme and channel conversion scheme. In digital hopping receiver, the GLONASS wide-band signals are first transformed to baseband and are sampled at very high rate (30 ~ 60MHz). Then digital high-speed PRN code loop and carrier loop demodulate the satellite signals by fast frequency hopping. This method will simplify the front-end, but on the other hand requires high processing speed and integrity of the digital part. In the channel conversion method, different GLONASS carrier frequencies are down-converted to the same IF frequency. So the digital processing unit is relatively easier to implement. But the front-end part is more complex and is difficult to debug.

Our design belongs to the latter method. Every three GLONASS IF signals are downconverted to three different frequencies. Because most part of the receiver can be achieved by an integrated GPS chipset, the receiver structure is greatly simplified, even though some extra glue logic needs to be added.

The GLONASS system has not yet reached its stable state. The changing of its frequency span will extend to next century. But the channels 1 to 6 continue to be used. This is why only a six-channel receiver is being implemented.

If more (up to 12) channels are to be configured, then the other channels are to be realized sequentially, for only two front-ends can be connected to one correlator. The hardware structure needs not change, only some software complexity is brought in.

CONCLUSIONS

The design scheme of a C/A code GLONASS receiver is presented. A GPS integrated chipset is used in the receiver structure. The feasibility of this structure is demonstrated. GPS front-ends and correlator are used realizing a six-channel GLONASS receiver. Only an external frequency synthesizer is needed for the tuning of the GLONASS channels. The realization has the advantage of simplicity and economy.

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