Journal of Electronic Research and Application

Research Article

Trifold frequency multiplier based on mixer for the feedback system of BEPC II

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Abstract: This paper will introduce the structure, development process, test and experiment of trifold frequency multiplier by using mixer and its application in accelerator fields. This invent includes a power splitter, a frequency doubler, a mixer, a bandpass filter, an amplifier and several RG233 cables. One 500MHz signal which always is provide by the timing system of the accelerator is input to a power splitter, a power splitter could divide one signal into two signals with equal magnitude, one is directly input to the LO port of mixer, the other is input to frequency doubler then 1.0 GHz signal will be got. This 1.0 GHz signal is input to the RF port of the mixer, then output at IF port of mixer, the frequency of the IF port signal is sum and difference of 500MHz and 1.0GHz, so 500MHz and 1.5GHz signal will be got. Then this signal is input to a bandpass filter whose centre frequency is 1.5GHz, so a clean 1.5GHz signal is got. The trifold frequency multiplier by using mixer is simple to operate, and it has good performance. In the experiments, the 500MHz signal was passed through the Trifold Frequency Multiplier to get the 1.5GHz signal, and its output amplitude stability is 0.49%, and its synchronization stability is 10.3 ps compared with the 500MHz input signal.

Publication date: December, 2019

Publication online: 31 December, 2019

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1 Introduction

In the field of accelerators, like as Beam Instrumentation system and RF system. Frequency down-converter electronics always be used to transfer the high frequency signal to baseband signal to match the ADC. The SNR (signal to noise ration) is better in high frequency band, and then in baseband frequency, the lower sampling frequency ADC can easily to look for. In down-converter circuits, the Local frequency always be used. It likes the carrier frequency, and always integer multiply the machine frequency, which is always 500 MHz or so. In the process of experiments, we sometimes need the high frequency signal of 1.5GHz, but such signal is not provided by the timing system. Consequently, the role of the frequency multiplier is highlighted. In addition, due to the different parameters and requirements of accelerators in application, the frequency multiplier has higher efficiency and stability in terms of amplitude stability and synchronization. For this purpose, Down-Converter is required to convert high frequency signals to baseband frequency signal. That is to say, the signals of 1.5GHz ± 250MHz selected by bandpass filter should be mixed with another signal of 1.5GHz by mixer to generate the desirable signals of baseband frequency which means the signal from DC to 250 MHz. And the frequency multiplier generates 1.5GHz signal during the processing. The frequency multiplier mainly amplifies the machine frequency in three times.

2 Experimental verification

2.1 Experiment

In this experiment, the 500MHz single frequency signal is generated by signal generator of Agilent E4434B, then use the frequency doubler and mixer to get the 1.5GHz signal. In the experiment, the relationship between the amplitude of 1.5 GHz output signal and the amplitude of 500MHz input signal was tested.

In this experiment, AV3656A vector network analyser (frequency range: 100 kHz~3GHz) is used in the laboratory to test the bandwidth of bandpass filter and amplifier. Network analyser is a kind of comprehensive microwave measuring instrument which is used to determine network parameters by scanning and measuring the wide band. The network analyser can directly measure the complex scattering parameters of active or passive, reversible or irreversible two-port and single-port networks and give the amplitude and phase frequency characteristics of each scattering parameter by sweeping frequency. The automatic network analyser can correct the measurement results point by point and convert dozens of other network parameters, such as input reflection coefficient, output reflection coefficient, voltage standing-wave ratio, impedance (or admittance), attenuation (or gain), phase shift and group delay, as well as isolation and orientation. Oscilloscope is used to transform the invisible electrical signals into visible images, which is convenient for people to study the changing process of various electrical phenomena. Spectrum analyser is a test and measurement equipment, mainly used for RF and microwave signal frequency domain analysis, including measuring signal power, frequency, distortion products. In this experiment, network analyser, oscilloscope and spectrum analyser are used to measure the performance of frequency multiplier.

In the process of using network analyser, the calibration is needed firstly. The Fig.12 shows the frequency band of BFCN-1525+, it has good performance from 1.438GHz to 1.694GHz. This band accords perfectly with the target frequency 1.5GHz.

The frequency component of the signal was tested with the model RSA5103B spectrum analyser (range: 1 Hz~3GHz). Spectrum analyser is a test and measurement equipment, mainly used for RF and microwave signal frequency domain analysis, including measuring signal power, frequency, distortion products. The frequency component of the output signal of 500MHz, the output signal of frequency doubler, the output signal of mixer, the signal after the bandpass filter and the signal after the amplifier are both observed on spectrum.

Frequency conversion gain also be tested by oscillation scope. The table 01 is the data acquired in experiment. The Fig.16 shows frequency conversion gain changes with the power of input signal. The conversion gain increases with the input signal power increases, the relationship of frequency conversion follows the exponential curve.

3 Results

In our experiment, the signal source we use is 502.5 MHz, with power 10.00 dBm. The main frequency 502.5 MHz is marked as M1 and the frequency 1.50375 GHz we want as the final output is one of the harmonic components of the input signal and it is marked as M3. M3 is 29.66 dB lower than M1, so the effect of direct using of a bandpass filter specific to frequencies around 1.5 GHz may not satisfy our requirements since M3 is too weak compared to M1. Thus, our purpose is to make 1.5 GHz become the main frequency. After being divided by the power splitter, one signal passes through the frequency doubler and its main frequency changes from 502.5 MHz to 1.00125 GHz. Two peaks, one at 498.75 MHz marked as M1 and the other at 1.50375 GHz marked as M3. It will result from the Δ and Σ operation in the frequency mixer. The power of M1 is 2.25 dB greater than the power of M3 so we need to use a bandpass filter to suppress peak M1. The waveform of the signal after the frequency mixer. Consequently, other frequencies can be suppressed with a difference of at least 16.48 dB. The series of an amplifier and an attenuator increases the power of the main frequency 1.50375 GHz from -30.35 dBm to -14.97 dBm, and the final difference between the main frequency 1.50375 GHz and the next highest peak 1.00125 GHz is 17.65 dB, which means that the power of the main frequency is approximately 58 times greater than that of the next highest peak. Therefore, we can say that the trifold frequency multiplier works. Also, we observed that the frequency conversion gain ratio increases as the power of the original source increases.

We test the bandpass filter with a network analyser, and the result shows that the passband width is from 1.43885 GHz to 1.69432 GHz. We also test the performance of the amplifier. The amplifier has a wide bandwidth from 639.28MHz to 1.365GHz and gain is 21dB (some 10dB attenuator is used).

As the whole one, the performance of trifold frequency multiplier is also tested. The amplitude RMS value of amplitude is 11mV, the stability is 0.49%. The time jitter between the input and output signal is shown in Fig.15. The time jitter is 10.3ps.

This study uses the idea of using a frequency mixer to achieve the frequency multiplication purpose. There is another way of achieving this purpose, because 1.5 GHz is one of the harmonic components of the original 500 MHz signal, so we can use a bandpass filter to filter out the frequency we want directly. Compared to this method, our method will be more effective in theory, because in the spectrum of the original signal, 1.5 GHz is a very weak component, which is approximately one 925th of the main frequency. This means that an extreme high-quality bandpass filter is required, which will lead to high costs. However, our method uses a frequency mixer to make the preferred frequency become one of the main frequencies, which reduces the demand on the quality of bandpass filter a lot.

4 Conclusion

In beam bunch by bunch feedback system of BEPCII (Upgrade of Beijing Electron Positron Collider), in order to obtain high SNR(Signal-to-Noise Ratio) signals, but at the same time to meet the requirements of ADC, it is usually necessary to transfer high-frequency signal to the baseband frequency signal in the down-converter circuit of front-end electronics. The main elements of the down-converter circuit is the mixer, which requires a local frequency of 1.5 GHz, which is tripled from the radio frequency of 500 MHz produced by the timing system of accelerator. In accelerator, the 500MHz RF frequency is always produce by a high stable signal generator and then this signal is distributed to everywhere and can be frequency multiplied or frequency divided.

In this research, the trifold frequency multiplier consists of a two way 0 degree power splitter with a frequency DC-4200MHz, a frequency doubler with input frequency of 300MHz-500MHz and output frequency of 600-7000MHz. a frequency mixer with LO input/RF output frequency of 10MHz-2000MHz and IF input frequency of DC-2000MHz. an amplifier with frequency of 1200MHz-1700MHz. a bandpass filter with frequency of 1480MHz-1570MHz, and several coaxial cables. The trifold frequency multiplier has the advantages of simple structure, convenient operation, excellent performance and low price.

The final output amplitude stability of the trifold frequency multiplier is very stable, the RMS value of the amplitude is 11 mV, the amplitude stability is 0.49%, and the phase stability is 10.3 ps, which fully meets the requirements of the feedback system.