Journal of Electronic Research and Application

Research Article

Trifold Frequency Multiplier by using Triode for the Feedback System of BEPC II

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Abstract: In BEPC II(Upgrade of Beijing Electron-Position Collider), multi-bunches and high current operation mode is usually used. Due to the influence of high frequency cavity structure or resistance impedance, the beam will be unstable. If the beam is unstable, the luminosity and brightness of the accelerator will be decreased. In order to improve the beam current and brightness of accelerator and the collider luminosity, the beam feedback system is needed to suppress the instability.

The trifold frequency multiplier by using triode is simple to operate, and it has good performance. In the experiments, the 500MHz signal was passed through the Triode Frequency Multiplier to get the 1.5GHz signal, and its output amplitude stability is 1.7mV, and its synchronization stability is 3.46ps compared with the 500MHz input signal.

Keywords: Beam feedback system, Trifold frequency multiplier, Frequency signal, BEPC II

Publication date: September, 2019

Publication online: 30 September, 2019

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1 Introduction

The basic principle of frequency multiplier is that the n-times harmonic waves are directly extracted from output signal that contains a wide band of frequencies, including fundamental frequencies and the n-times frequencies, and the other components will be restrained.

In the field of accelerators, we must apply the 500MHz signal which is machine frequency of accelerators to carry out experiments and tests. 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, which is better for Analog to Digital to further processing. 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 250MHz. And the frequency multiplier generates 1.5GHz signal during the processing. The frequency multiplier mainly amplifies the machine frequency in three times.

2 Principle of trifold frequency multiplier

When receiving single frequency, the nonlinear effect of diode and triode leads to output the higher harmonic component. The construction of frequency multiplier utilizes this property. The frequency multiplier can be separated into parametric frequency multiplier (varactor diode frequency multiplier, step diode frequency multiplier), triode frequency multiplier and phase-locked loop frequency multiplier. Parametric frequency multiplier consists of nonlinear circuit. One of the most widely used nonlinear reactance devices is the varactor diode.

By using the properties of nonlinear capacitance, the multiplier effect can be accomplished by parametric energy transfer effect. Another kind of multiplier is

the step diode, which can generate dramatic reverse impulse current, leading to the formation of luxuriant harmonic-frequency components. This is why the step diode can achieve high order frequency multiplication, which can reach forty times. For the short wave and ultra-short wave, triode frequency multiplier composed by the crystal triode is usually used. The amplitude of each harmonic current decreases rapidly with the increase of harmonic frequency. The frequency divider is inserted into the phase-locked loop, and the frequency multiplication of any multiple can be achieved by changing the frequency division number. PLL frequency multiplier is widely used in transmitter, frequency synthesizer and other information transmission and processing systems.

3 Experimental verification

In this experiment, the 500MHz single frequency signal is generated by signal generator of Agilent E4434B and then be input into the amplifier with the model ZFL-1000LN. The nonlinear effect of the amplifier circuit is used to generate higher harmonics. 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 analyzer (frequency range: 100 kHz~3GHz) is used in the laboratory to test the bandwidth of bandpass filter. Network analyzer is a kind of comprehensive microwave measuring instrument which is used to determine network parameters by scanning and measuring the wide band. The network analyzer 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 analyzer 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 analyzer 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 analyzer, oscilloscope and spectrum analyzer are used to measure the amplitude-frequency response of frequency multiplier to test the effect of frequency multiplier.

In this experiment, model 760Zi-A oscilloscope (sampling rate: 20GHz) was used to observe the amplitude and distortion of the signal after the amplifier ZFL-1000LN The waveform is distorted compared by standard sinewave and shows high harmonic waves in the waveform.

The conversion gain increases when the signal power is smaller than -16dBm, but when the signal power is bigger than -16dBm, the conversion gain decreases with the input signal power increasing.

4 Conclusions

This frequency multiplier mainly includes: a low frequency amplifier, two filters, and a high frequency amplifier. The nonlinear effect of the amplifier which can change the waveform and produce harmonic waves is employed to accomplish this goal. The front-end amplifier ZFL-1000LN is used in this multiplier frequency, its working frequency between 100 kHz to 1000 MHz, it is good for 500 MHz signal. Through the test, the phenomenon can be found that obvious nonlinear effect occurs when the power of input signal is above -15dBm, that is to say, harmonic waves will be got. The obtained amplitude of 1.5 GHz is large enough to be used. The noise of this element is also in a suitable range for the use of the accelerator feedback system.

After the high-frequency waves are produced by nonlinear-transformation circuit, the third harmonic frequency signal can be achieved by LTCC Bandpass filter. When selecting a LTCC Bandpass filter, attention should be paid to its filtering range, with 1.5GHz in the middle of the range to avoid other unwanted frequency bands being filtered out. LTCC Bandpass Filter, BFCN-1525+, whose working frequency range is between 1480MHz to 1570MHz. This microwave elements is used to efficiently filter out signals of 1.5GHz.

However, passing through the band-pass filter and nonlinear-transformation circuit will cause the loss of intensity of the needed signal. Therefore, the amplifier is needed to magnify the intensity of these signals. The amplifier ZHL-1217MLN is used. It operates at frequencies ranging from 1200MHz to 1700MHz, which amplifies the required 1.5GHz signal very well. This amplifier has low noise - up to 1.5dB.