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STRIPLINE BEAM POSITION MONITOR FOR THZ SOURCE BASED FEL *

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Abstract

A 14MeV Linac with both the micro-pulse repetition rate 2856MHz and the macro-pulse width 6μs for the THz Source Based FEL was proposed. In order to measure the beam position, a stripline beam position monitor (BPM) was designed, and a commercial BPM electronics Libera Brilliance Single Pass was adopted. As the input carrier frequency of the BPM electrode signal is 2856MHz, but the operating frequency of the Libera Brilliance Single Pass is 500MHz, so a front-end electronics was needed before the electrode signals feed into Libera Brilliance Single Pass. The front-end electronics was designed to make the BPM electrode signals of 2856MHz convert to 500MHz.

INTRODUCTION

In the 14MeV Linac with both the micro-pulse repetition rate 2856MHz and the macro-pulse width 6μs for the THz Source Based FEL [1], a stripline BPM is designed in order to measure the BPM signal with Libera. The operating frequency of the Libera Brilliance Single Pass is 500MHz. In order to measure the 2856MHz signal, a front-end electronics was needed. This front-end electronics is used for the mixing of electrodes' inductive signals, which down-convert the signal from 2856MHz to 500MHz. The ADF4360-1 chip [2] is taken as the local oscillator, which produce a 2356MHz signal. And this chip needs a MCU to control it, so we select STC12C2052AD chip, which can output a signals of 2356MHz and mix with electrode signals. The ADE-30 chip is chosen as the mixer. The signals after mixing are feed into Libera Brilliance Single Pass. Finally we add a 6dBm attenuator before the signals entering Libera Brilliance Single Pass .

SCHEME BLOCK DIAGRAM

The BPM mesurement system consists the stripline BPM, the front-end electronics, and the Libera Brilliance Single Pass. The schematic block diagram of the system is shown in Fig. 1.

Because the operating frequency of the Libera Brilliance Single Pass is 500MHz, so the front electronics was needed before the electrode signals enter to Libera Brilliance Single Pass. The front electronics consists a local oscillator to produce a 2356MHz signal, four mixers, and four attenuators.

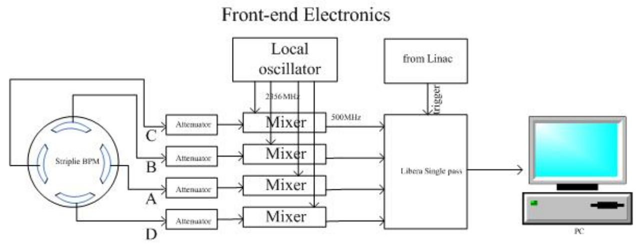

Figure 1: Schematic block diagram.

DESIGN OF STRIPLINE BPM

Stripline BPM is a common type of beam position detector for Linac [3]. In order to meet the need of the 14MeV Linac, a few parameters are calculated, which are electrode length l, electrode inner radius r, electrode opening angle ϕ, and electrode thickness t.

Selection of the electrode thickness is mainly considered in mechanical strength and deformation of the electrode in the electromagnetic environment. According to experience we set the electrode thickness t = 1.5 mm. The electrode inner radius r and electrode opening angle ϕ are mainly determined by the 50Ω impedance matching of stripline electrodes.

The signal of the BPM can be divided into the following pattern: summode(Z_{sum}), dipole mode(Z_{horz} , Z_{vert}), quadpole mode(Z_{quad}). Four modes of the strip electrodes was shown in Fig. 2.

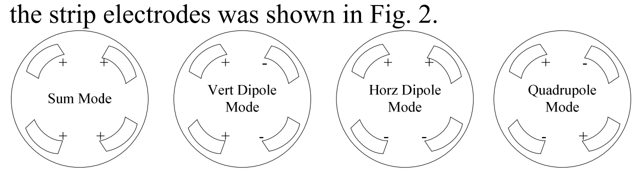

Figure 2: Four modes of the strip electrodes.

In order to ensure impedance matching of stripline BPM [4], the impedance under different mode must meet the formula $R_0^2 = Z_{sum} Z_{quad} = Z_{horz} Z_{vert} = 50\Omega^2$.

The capacitance between the electrode stripline and the vacuum chamber is C, according to the following formulas, the characteristic impedance of the stripline in four modes can be calculated.

$$\begin{cases} Z_0 = \dfrac{1}{vC} \\ E = \dfrac{1}{2} C \left(V_1 - V_2 \right) \end{cases} . \quad (1)$$

We can get resistances of four modes Z_0 , $Z_0 = 1/vE$, where v is speed of light, V_1 and V_2 are the voltage between electrodes and the vacuum chamber. we can use

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POISSION SUPERFISH software to get the characteristic impedance. By changing the parameters in order to meet the 50Ω impedance matching, we can get electrode inner radius r =14.0mm and electrode opening angle ϕ =30^0. In this case, $Z_{horz} = Z_{vert} = 49.17\Omega$, $Z_{sum} = 53.17\Omega$, $Z_{quad} = 47.72\Omega$, the impedance under different mode meet the formula $Z_{sum}Z_{quad} \approx Z_{horz}Z_{vert} \approx 50\Omega^2$

As the main frequency of electrode signal is 2856MHz, we select the length of the electrode $l = 5c/4f = 131.30$mm. The frequency response of the stripline BPM was shown in Fig. 3. This shows that the frequency response of the stripline BPM is the peak value at 2856MHz.

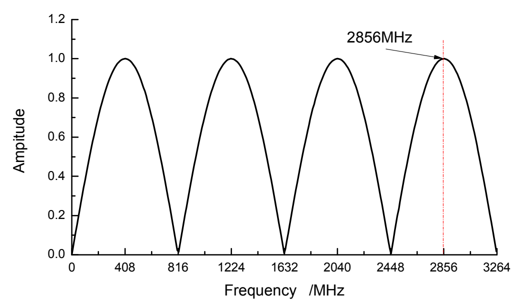

Figure 3: The frequency response of the stripline BPM.

In conclusion, we can obtain the designed parameters of stripline beam position monitor. The cross-section of the stripline BPM was shown in Fig. 4.

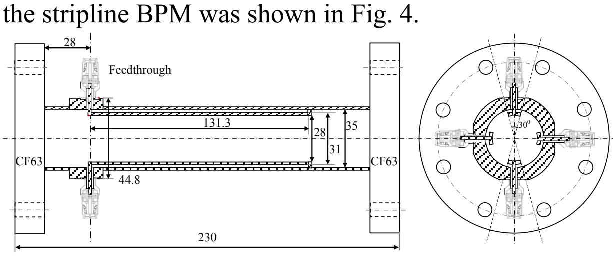

Figure 4: The cross-section of the stripline BPM.

According to above parameters, the position sensitivity of this stripline BPM can be calculated by [5]:

$$S_{x,\Delta/\Sigma} = S_{y,\Delta/\Sigma} = 4\frac{\sin(\phi/2)}{\phi}\frac{1}{r} \approx 0.141mm^{-1}$$

FRONT-END ELECTRONICS

First we design a local oscillator module to produce a 2356MHz signal. ADF4360-1 chip was selected, the frequency range of the ADF4360-1 chip RF output signal is 2050 MHz to 2450 MHz [6]. The module can produce a stable 2.356GHz signal. The circuit parameters can by designed by ADI's design software ADF4360-X Evaluation Software. We can use data sheet of ADF4360-1 chip to calculate parameters of the circuit, and calculate output frequency.

We can get output frequency from the formula below:

$$f_{out} = \left(B \times P + A\right) \times f_{ref} / R \qquad (2)$$

where f_{out} is the output frequency of the VCO, P is the preset modulus of the dual - modulus prescaler (8/9, 16/17, and so on), B is the preset divide ratio of the binary 13-bit counter (3 to 8191), A is the preset divide ratio of the binary 5-bit swallow counter(0 to 31), f_{ref} is the external reference frequency oscillator.

This chip needs a MCU to control it, so a program was written to MCU to change ADF chip register value. We can reach frequency that we want, and the program must conform timing of data sheet [6]. If this program need to be written to MCU, its P1.5, P1.6, P1.7 port should connect with ADF4360-1 chip's CLK, LE, DATA. We can edit the appropriate procedures to reach a timing that we need. The timing was shown in Figure 4. After these conditions are all set, the chip can generate 2356MHz by MCU I/O port input. Finally this signal can mix with stripline signal to 500MHz, which will be fed into Libera, and can obtain beam location by observing processing data of Libera in computer.

To design the local oscillator, here ADI company production ADF4360-1 chip was used. The design of it's external circuit is very important, because this chip need external oscillator. A 10 MHz crystal oscillator was taken, and it is also the temperature compensation crystal chip for ADF4360-1. The stability can reach 0.6 ppm, so it can reduce the jitter of signal. Others between CP port and VTUNE port access to third-order passive low-pass filter, we use ADI's software ADIsimPLL to design it's parameters, which is shown in Fig. 5. The design of other ports can refer to its manual [6].

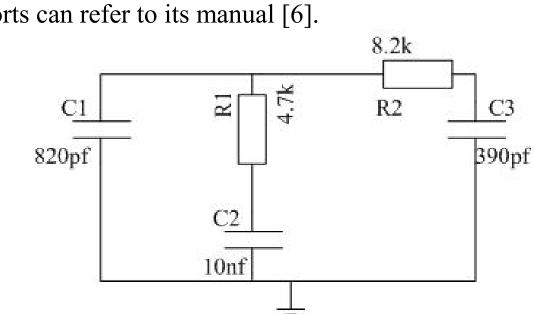

Figure 5: Third-order passive low-pass filter.

The design of ADF chip uses a microprocessor STC12C2052AD to generate control signal, and ADF4360-1's CLK, DATA and LE ports connect with respectively microprocessor's P1.5, P1.6, P1.7 port, it's timing should meet Fig. 6 [6].

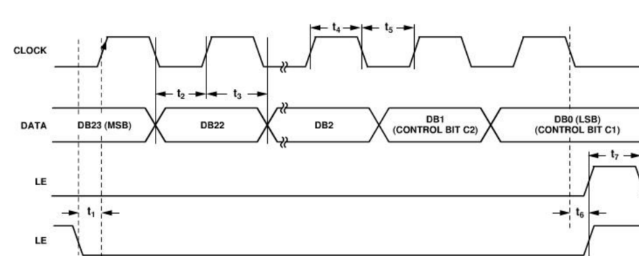

Figure 6: Timing diagram.

We write register parameters to microprocessor respectively, R counter latch is 3000C9H, C control latch is 8FF108H, N counter latch is 017012H. We can edit a programming about HEX file by Keil uVision4, which is

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written into STC12C2052AD by STC-ISP software. Then use MCU to control the ADF4360-1 chip to output frequency by linking on the power, generating a frequency 2356MHz, its full circuits was shown in Fig. 7.

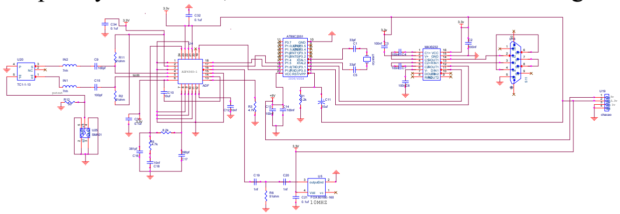

Figure 7: The hardware circuit diagram of local oscillator.

We used spectrum analyzer to measure the local oscillator signal, which cause the attenuation of 2 dBm. The spectrum analyzer need to be connected an attenuator of 10dB, which can prevent spectrum analyzer from damage by large signal.

Signal spectrum of the local oscillator was measured using spectrum analyzer as shown in Fig. 8, the central frequency is 2356MHz, the peak jitter of this signal reached 1%, this is entirely consistent with the design requirements of the circuit.

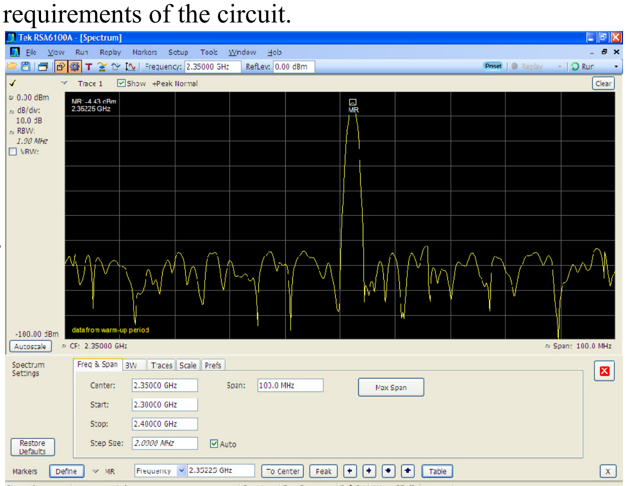

Figure 8: The spectrum of the local oscillator.

We chose ADE-30 chip for the mixer. The above 2356MHz signal of local oscillator is divided into four signals using a power divider. Then the signals are mixed with four BPM signals. On table test, we use signal generator to generate 2856MHz signal to simulate the BPM signal. The signals after mixer were measured by spectrum analyzer, the results were shown in Fig. 9. These show that the four frequencies of four mixers are the peak value at 500MHz.

We can feed these signals into Libera to get signals of BPM. By calculating the signals in Libera Brilliance Single Pass [7], finally we can get the beam position.

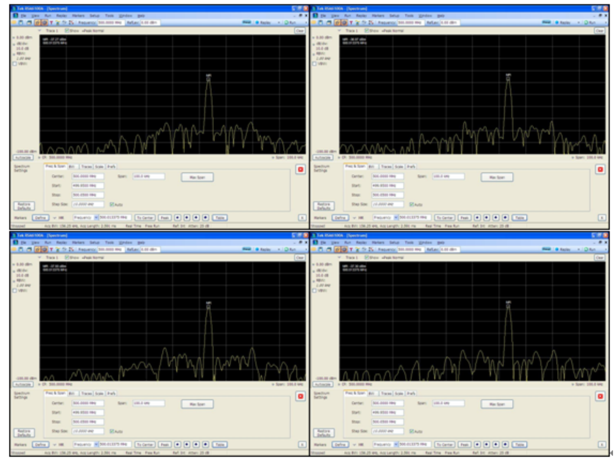

Figure 9: Four 500MHz signals after mixed.

CONCLUSION

In this paper, we designed the stripe BPM and calculate its parameters. We also designed a front-end electronics for Libera Brilliance Single Pass, we used ADI's ADF4360-1 chip, which is high stability, convenient debugging, low power consumption and cost, etc. The BPM system will be on-line tested.

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