A Method of Frequency Following of the LINAC with Power Feedback

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Abstract

There are three factors to influence the frequency stability of the magnetron which is the power source of the LINAC: the change of the modulating voltage,the slow change of the environment temperature and the unstable reflection from the accelerating tube with the power feedback.We can use a decreasing Q circuit to stabilize the modulating voltage. The frequency shift caused by the change of the environment temperature can be decreased by a frequency stabilization system. The frequency change introduced by the unstable reflection can be decreased by an adaptive frequency following controller. When an adaptive control loop is added to the feedback loop of the frequency stabilization system,the adaptive frequency following will present. A digital controller which is a single chip microprocessor is used to perform a rapid frequency stabilization and a slow frequency following.The optimal frequency following is realized by maximizing the area of the superposition envelope at the entrance of the accelerating tube. In order to realize the rapid frequency stabilization,a high speed SCR system with three current converters in sequence is used to drive the stepping motor of the frequency stabilization system.

Introduction

The high utilization factor for the power source is a distinguishing feature of the LINAC with the optimal coupling feedback. We can adjust the two phasers (in Fig. 1) again and again to minimize the absorbting power in the load,as a result,the input power of the accelerating tube will be maximum.The oscillation frequency of the magnetron whether to stable or not is very important for the accelerator,it is necessary to find a method of the frequency stabilization suitable for the accelerator with the power feedback.

Factors to Influence the Frequency Stability

There are three factors to destroy the stability for the oscillation frequency of the magnetron:

a) The ripple at the top of the modulating pulse and the change of the amplitude of the modulating voltage causes a fast change of the oscillation frequency for the magnetron.

b) The change for the power spectrum of the magnetron caused by the reflection introduces a output change of the frequency discriminator,the servo mechanism of the frequency stabilization system will drive the tuning bar of the magnetron and change its oscillation frequency,then the oscillation frequency will be deflected from the operating frequency of the accelerator.For the LINAC with the feedback,the frequency deflection is very serious.

c) The change of the environment temperature causes a slow shift of the oscillation frequency for the magnetron.

Adaptive Frequency Following

For the fast change and slow shift of the oscillation frequency we can use a decreasing Q circuit in the pulse modulator and a frequency stabilization system to reduce the frequency change,as for the frequency unstability caused by the change of power spectrum of the magnetron,an adaptive frequency following controller can be used to decrease the unstability,then the long-time stability for the oscillation frequency is ensured.

Energy of the electron beam is decided by the microwave power at the entrance of the accelerating tube,the magnitude of the entrance power may be represented by the area of the superposition envelope,then the envelope area can be regarded as a performance functional,an adaptive mechanism tuns the cavity (Q=10,000)which is treated as a frequency discriminator to maximize the envelope area.As a result,the beam intensity will be maximum for a fixed energy.

We use a single chip microprocessor as the digital controller,it provides three functions:phase adjustment,frequency stabilization and adaptive frequency following.The output of the cavity detector is a pulse current,a current integrator is used to find the signal area of the detector output,a DC signal which is obtained by holding the signal area is converted by an ADC into an 8-bit digital word and is transfered into the single chip microprocessor.In order to stabilize the oscillation frequency of the magnetron near the resonance frequency of the cavity,an one-demension search method is used.If the spectrum form of the magnetron has a fast change, it will cause several difficulties for the search method,for example,the exactness of the frequency stabilization may be reduced, the speed of the frequency following will be influenced etc.After realizing the frequency stabilization,the adaptive frequency following loop added onto the frequency stabilization loop will begin to operate,an area signal of the superposition envelope without the beam load at the entrance of the accelerating tube will be searched to its extremum and holded near the extremum by means of tuning the cavity.As a result,when the beam current with fixed energy exists,its intensity will be maintained near the maximum.If the adaptive loop fails,the accelerator will still operate and the beam current will not be maintained at its maximum.

Stepping Motor Servo

The stepping motor is a pulse motor which is used in the accurate control system, high accuracy,no accumulation error and wide range of the stepping rate are three advantages of the motor.In the frequency stabilization system,the cavity and the magnetron are tuned by the motor respectively,the one is drived by the repetition pulses with a low speed,the other is drived by the variable speed pulses which are dependent on the frequency deflection of the magnetron from the resonance frequency of the cavity,then the slow frequency following and the rapid frequency stabilization are performed independently.

Fig.2 shows a common transistor driver of the stepping motor,the maximal effective

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stepping rate for dual-three beat status is about 300 steps per second(output moment:3kg-cm),the winding inductance L_0 and the series resistance R_0 determine the time-constant L_0/R_0 ,it confines the rate of current rise in the winding,then the maximal effective stepping rate is restricted.In order to increase the stepping rate,the one of effective methods is to be introduced the SCR current converters into the motor driver as shown in Fig.3, the maximal effective stepping rate can be increased to about 550 steps per second(output moment:3kg-cm).This SCR driver contains three current converters,they must operate sequently .Pulse A fires the SCR1,then capacitor C with an initial voltage E_1 begins to discharge through inductance L_0 and SCR1.When $T=\pi\sqrt{LC}$ V_a equals $-E_1$ and SCR1 is interrupted.Pulse B fires the SCR2s,the voltage $-E_1$ on capacitor C will interrupt two SCR4s.As for which SCR4 fires after $V_a=0$ will be decided which gate is biased a positive voltage by the reversing divider.As the voltage on capacitor C rises up to its extremum,pulse C fires the SCR3,the capacitor C discharges through the two firing SCR4s and its series inductors,then this rate of current rise in inductor L_0 will be much larger than that one in Fig.2.In result, the maximal effective stepping rate increase.

Conclusion

The adaptive frequency following method is suitable for ensuring the high utilization factor of the LINAC with the optimal coupling power feedback.

References

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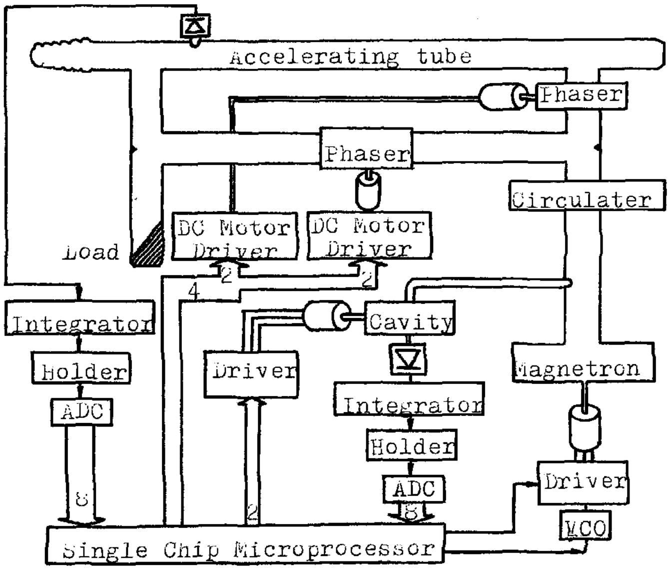

Fig. 1

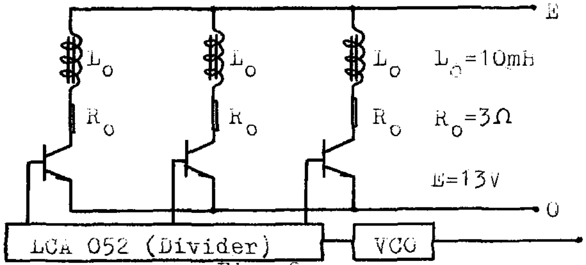

Fig. 2

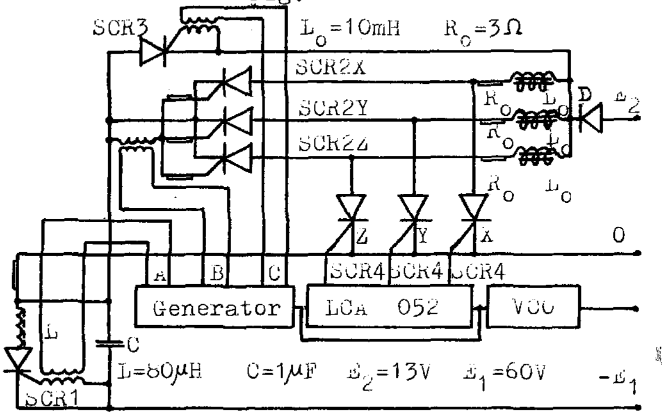

Fig. 3