RF System Stability Analysis by Simulink on Matlab

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Abstract

Matlab is a widely used software in the field of control. In this paper, we analyze the stability of RF system with it. A RF system is made up of beams, cavities and low level control loops. There are complicated feedback relationships among the phases and amplitudes. In this paper, we present a mothod to analyze the RF control system by Simulink on Matlab. We got some fundamental results. Compared with other methods, it′s easier to manipulate.

1 Introduction of the RF system

RF system is one of the most important subsystem in an accelerator. RF system accelerates beam, supplying the power of beam. The power feed into the RF system is used to create high electronic field strength and supply the energy lost while beam goes through undulator wiggler or B-magnet.

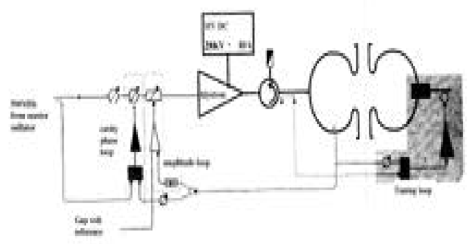

Fig.1 Block diagram of RF system

A RF system always includes cavity, power source, and low level control system. The low level control system is used to keep RF system in a stability area.

The stability of RF system is usually restricted to $\Delta V / V \le 1\% \ and \ \Delta\varphi \le 0.5°$ for a 3rd generation synchrotron. A long and stable running of accelerator demands high quality of RF system.

To analyse the performance of RF cavity, F. Pedersen has built a transfer model of cavity including the interaction of beam and cavity, which is widely used in this area. Considering the feedback loop over Pedersen model, we can get a pedersen model with feedback (Fig. 2). In the following section, we will analysis the stability of RF system based on such a model.

To analyse the system more efficiently, we select Simulink on Matlab to calculate the system, instead of C or FORTRAN programming. Similarly works have been done by R. Tighe, SLAC on PEP-II. By learning his idea and method, we analyze a supposed system, which is based on SSRF.

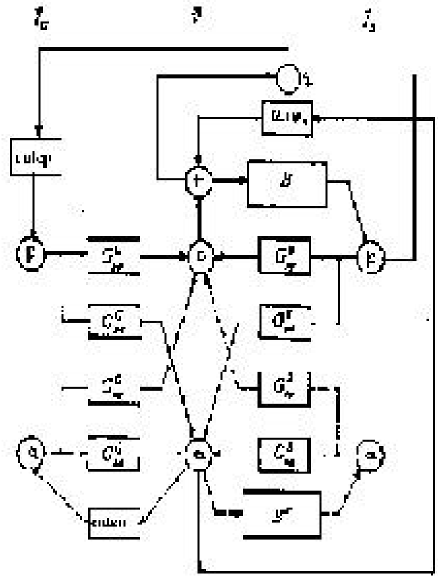

Fig. 2 The Pedersen Model with feedback

2 Stability analysis of RF system by simulink on matlab

To analyse the stability of RF system, we follow these steps:

i) Give the simple model of RF system as block diagram

ii) Express the system in simulink

iii) Write m-file in matlab to calculate the stability area and draw stability area

2.1 Single cavity stability

First we calculate the situation of single cavity. Such a situation is a bit simple than real system that is always has double or more cavity. We can simplify the system to the following case:

2.1.1 No loop system

No loop is added to the system, so the system contains cavity, RF power source and beam only, which is a basic system. The stability of this system can be calculated out analytically and got Robinson stability limit. Our result can be compared with theoretical result.

2.1.2 System with phase loop only

By calculating the stability area of such a system, we can find that the stability limit moved, system can be stabilized in part of area while $\varphi_z < 0$.

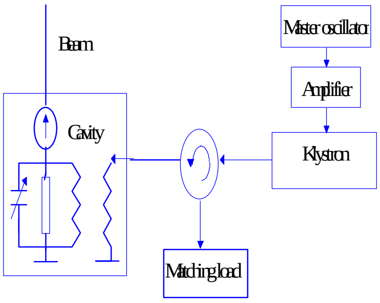

Fig. 3 No loop system

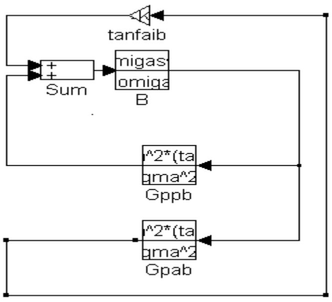

Fig. 4 No loop system expressed in Matlab

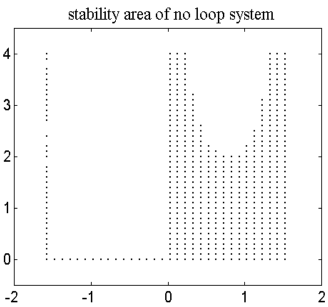

Fig. 5 Stability area of no loop system

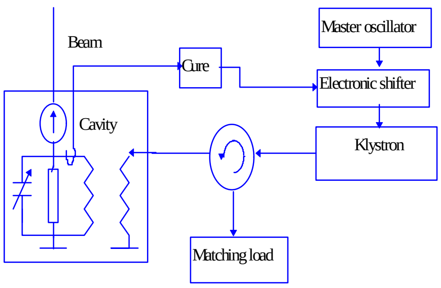

Fig. 6 System with phase loop

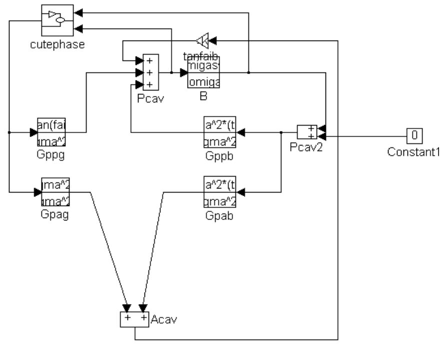

Fig. 7 System with phase loop express on matlab

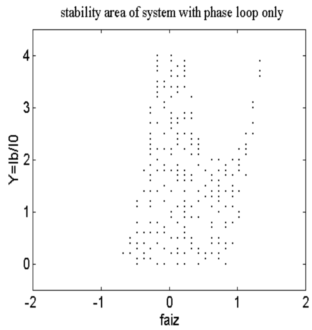

Fig. 8 Stability area of system with phase loop

2.1.3 System with amplitude loop and phase loop

By adding phase loop and amplitude loop to basic system, we get the system near to a real system in single cavity situation.

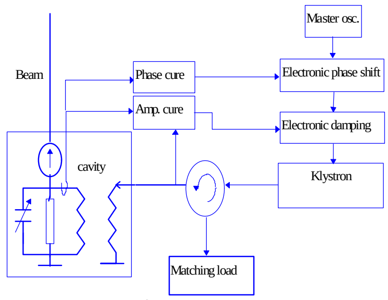

Fig. 9 Block diagram of system with phase and amplitude loop

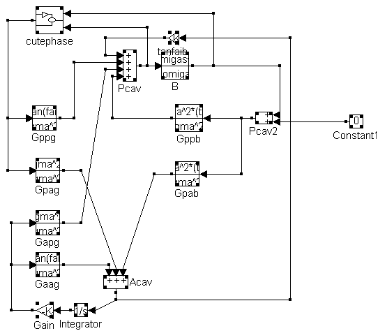

Fig. 10 Expression of system with phase and amplitude loop on matlab

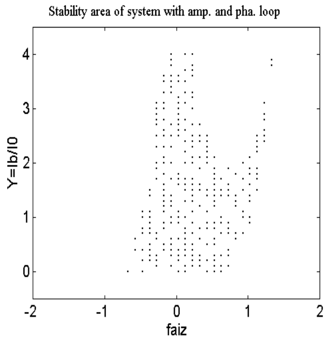

Fig. 11 Stability area of system with phase and amplitude loop

2.2 Double cavities stability analysis

Next, we analyse the stability of system with double cavities based on the single cavity.

Consider two cavities whose power is feeded by two different klystrons. There is only beam transfer between two cavities, that is the first cavity act on the beam and causes the changing beam phase, then the changed beam becoming the input of second cavity. We also suppose the error of phase and amplitudes of the power feeding into two cavities are white noise.

2.2.1 Block diagram of double cavity RF system

The follow diagrams show the stability area of phase loop only, amplitude loop only, phase and amplitude loop without and with white noise.

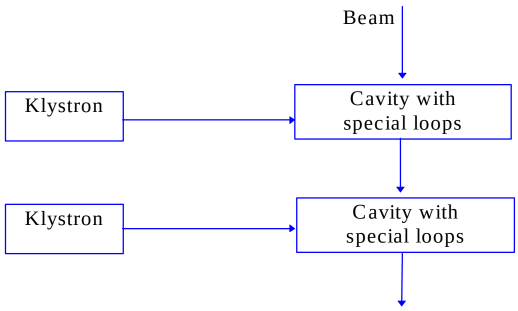

Fig. 12 Block diagram of double cavity system

2.2.2 Express on matlab

Compose the component of cavity, then the input of cavity is phase of beam, white noise of klystron s amplitude and phase.

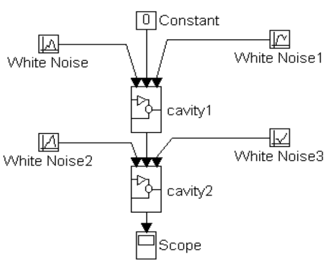

Fig. 13 Expression of double cavity system

2.2.3 Stability areas of different cases

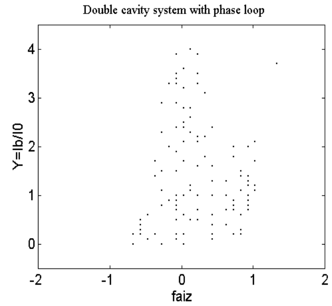

Fig. 14 Stability area of double cavity system with phase loop only

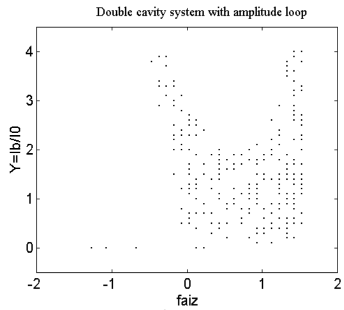

Fig. 15 Stability area of double cavity system with amplitude loop only

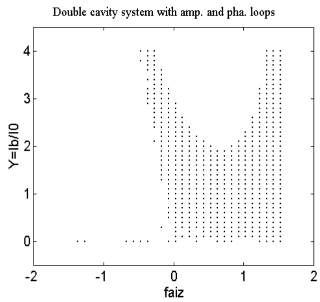

Fig. 16 Stability area of double cavity system with amplitude and phase loop

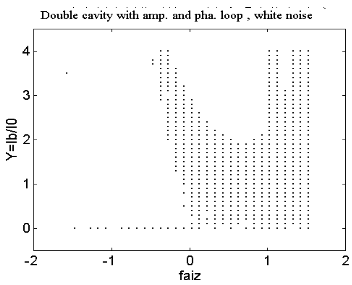

Fig. 17 Stability area of double cavity system with amplitude and phase loop and white noise in the output of klystron on phase and amplitude

2.3 Influence on system stability area by modifying amplitude loop (no phase loop)

In order to analysis how the system stability rely on the intensity of loops, we try to change the feedback intensity and calculate the stability area.

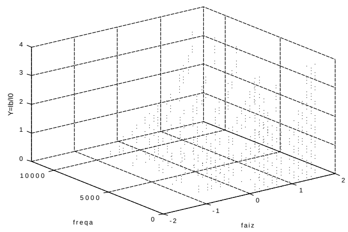

Fig. 18 System stability area with changing amplitude feedback (no phase loop)

2.4 Influence on system stability area by modifying phase loop (no amplitude loop)

We also did similar work to phase intensity: that is, select the amplifier as 0,2000,4000,6000,...12000, we can get different stabilities as follow:

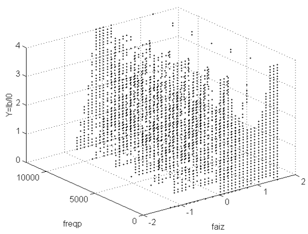

Fig. 19 Systemstability area with changing phase feedback (no amplitude loop)

3 Summary

Simulink on Matlab is a useful tool on the analysis for RF control system. Similar works have been done by SLAC, but never seen in China. We learn the method and try to do some advanced analysis facing real system. This will help for the design and optimization of the system.

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