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Discovery, accelerated

Chatter reduction in sliding mode tuner controller using skipping surface

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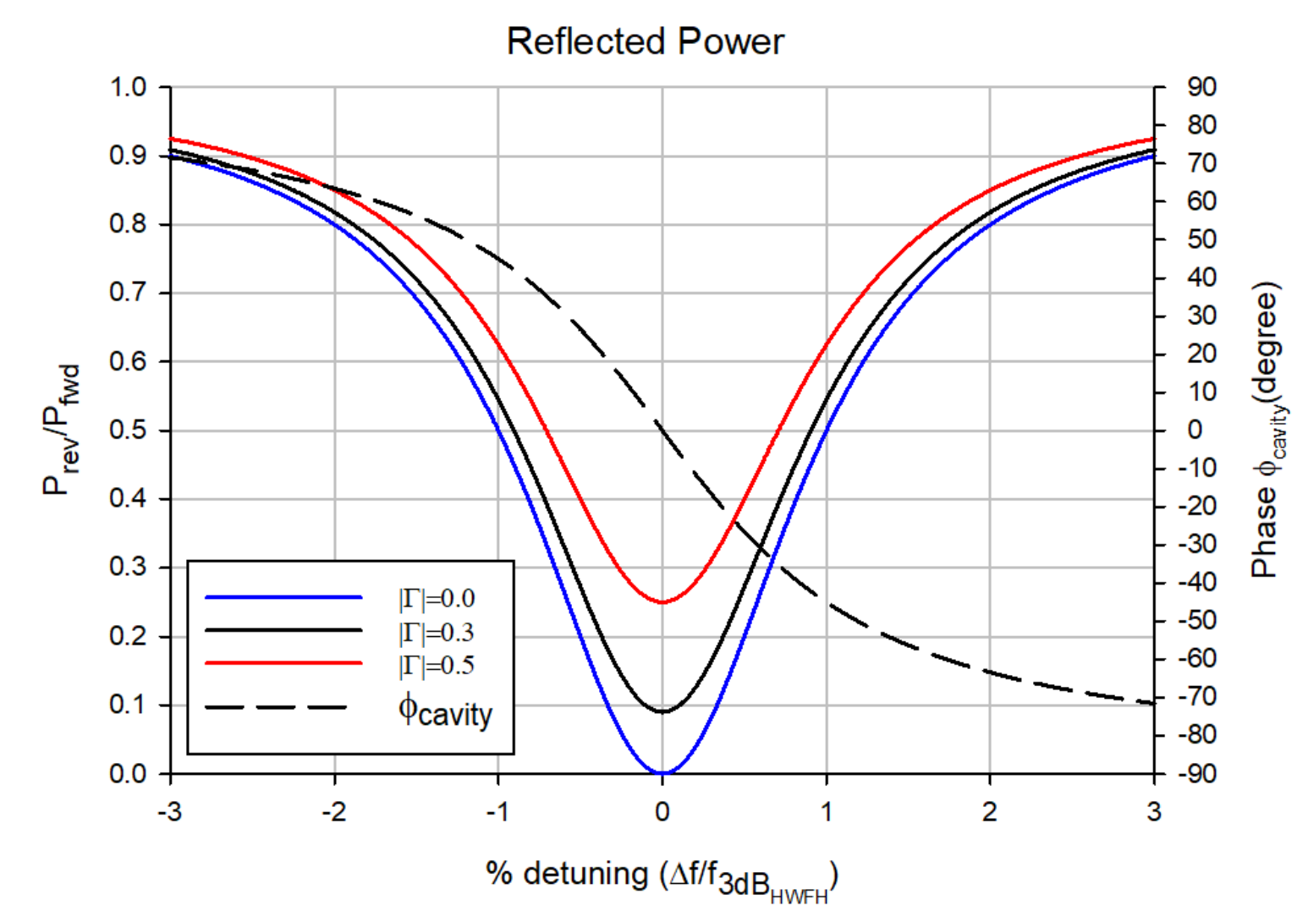
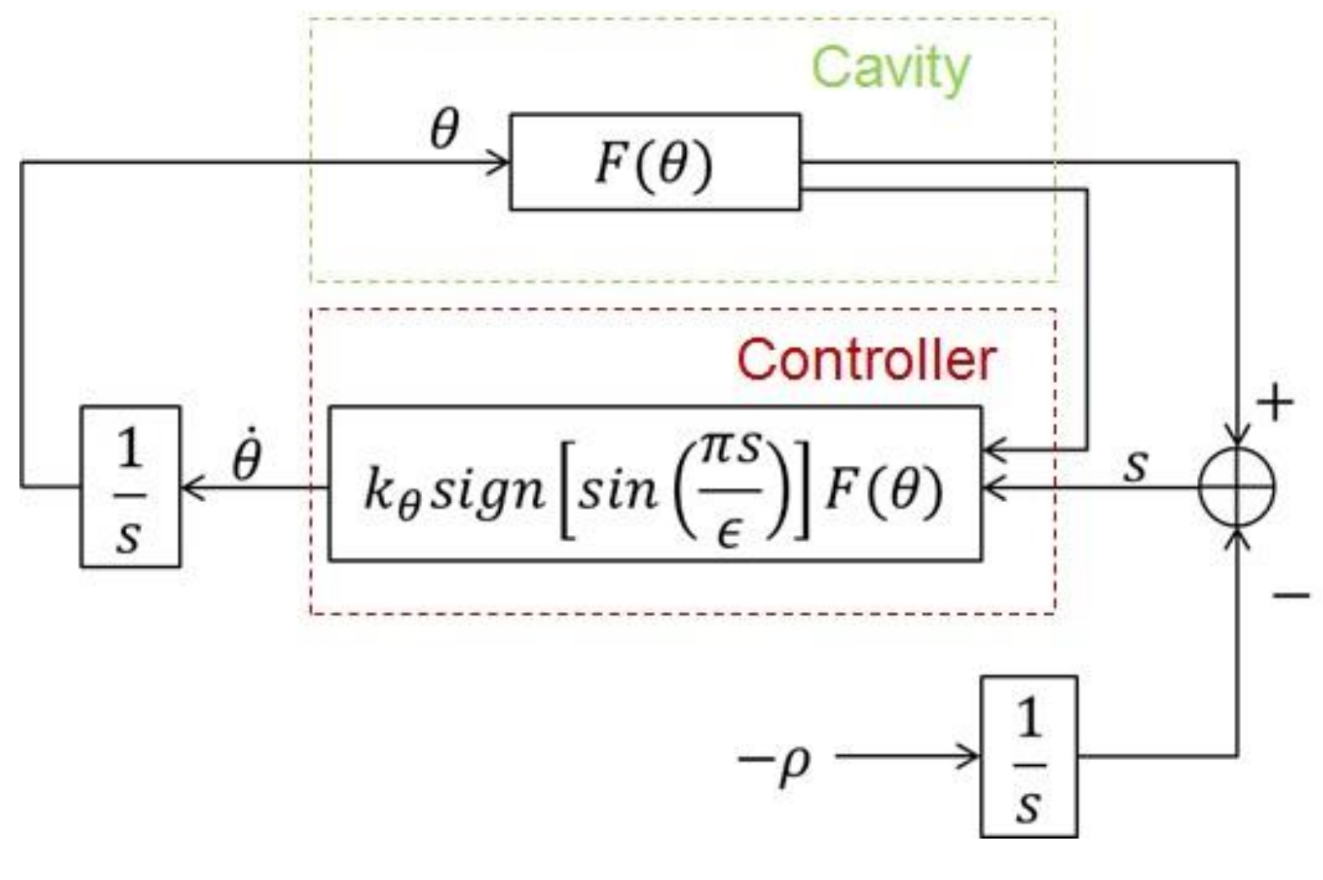
ABSTRACT

TRIUMF ISAC 1 tuning controllers operate using minimum seeking sliding mode controller to minimize the reflected power in their cavities. As with all minimum seeking algorithms, chatter present in the controller can degrade its performance and cause unnecessary mechanical wear. By observing the rate at which the minimizing function approaches the sliding surface, it is possible to determine whether a change in direction is necessary, thereby reducing the amount of chatter throughout the minimum seeking process.

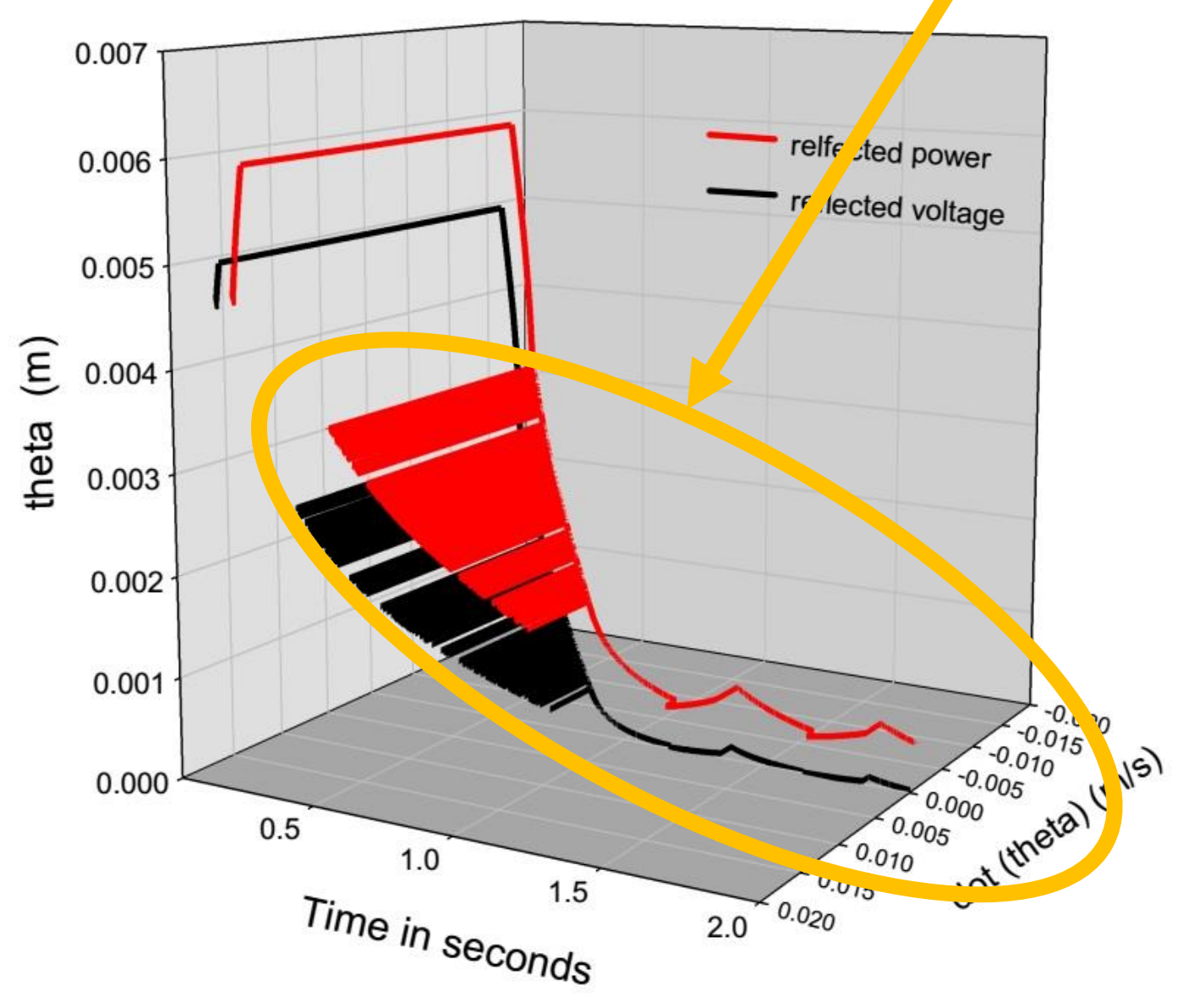
Sliding mode frequency tuning at TRIUMF:



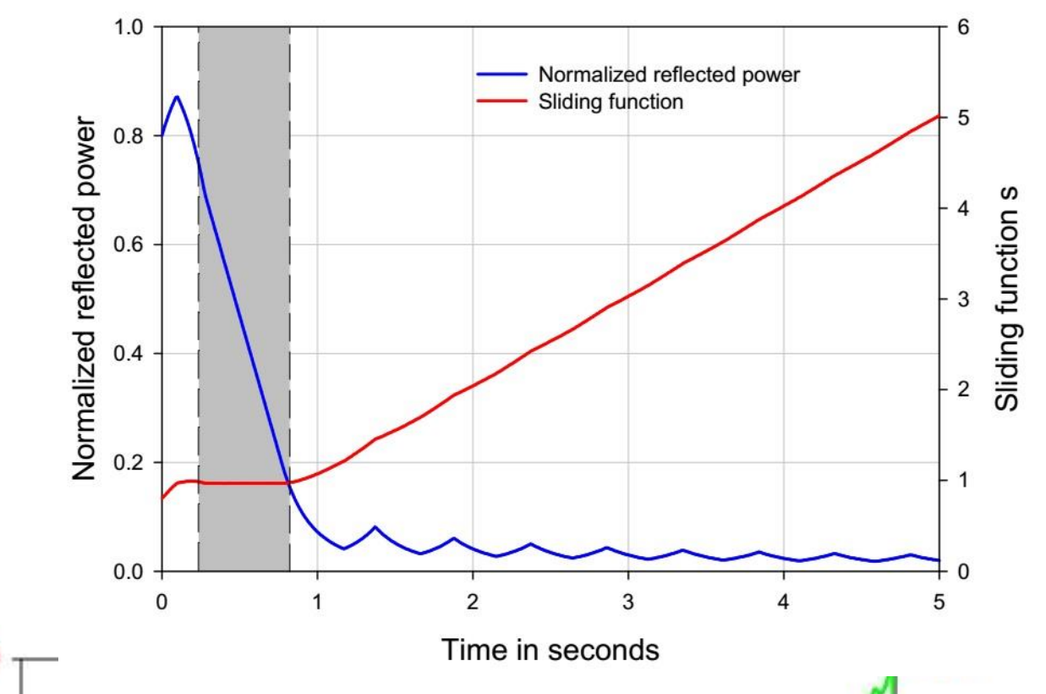


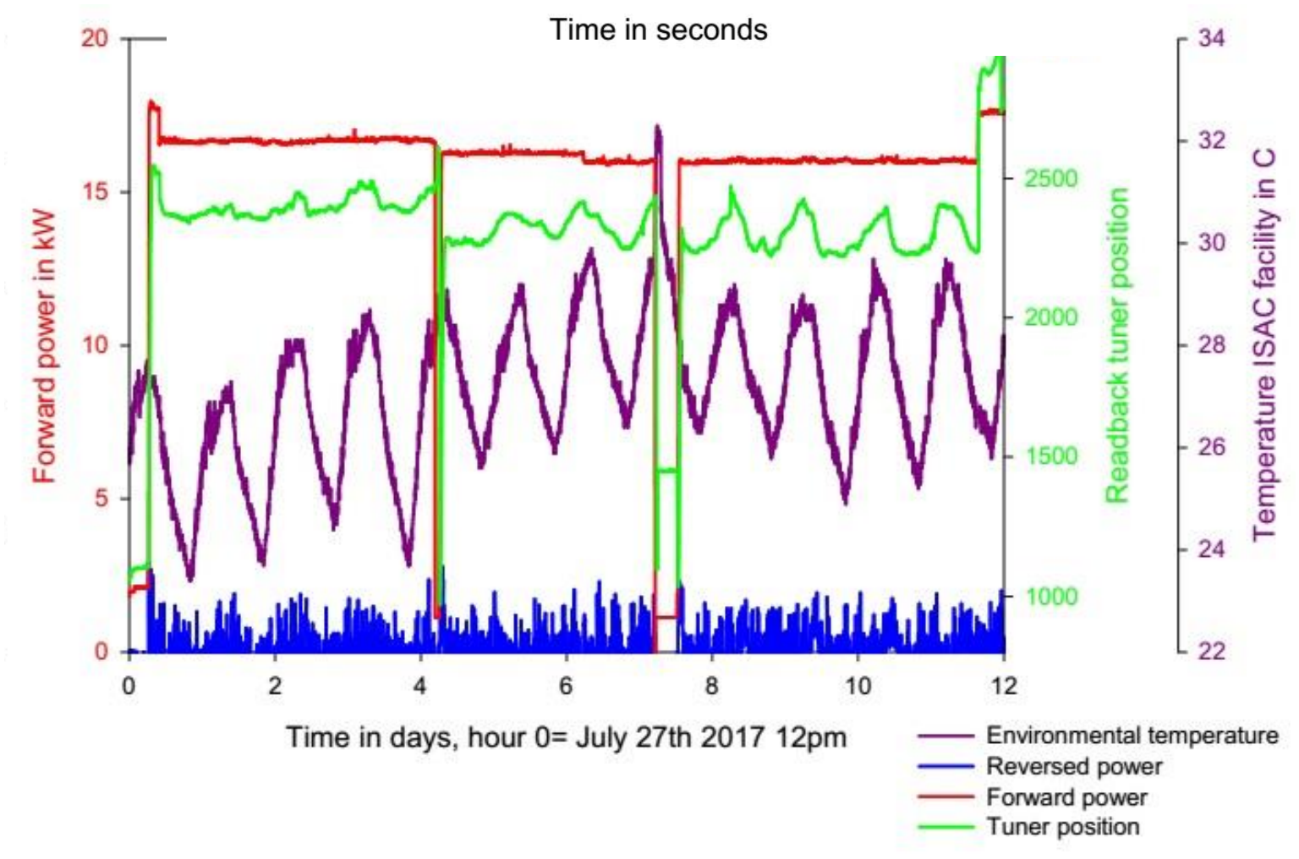
$$\dot{\theta}=k_0 sign\left[\sin\left(\frac{\pi s}{\varepsilon}\right)\right]F(\theta)$$

$$s(t)=F(\theta)+\rho t$$



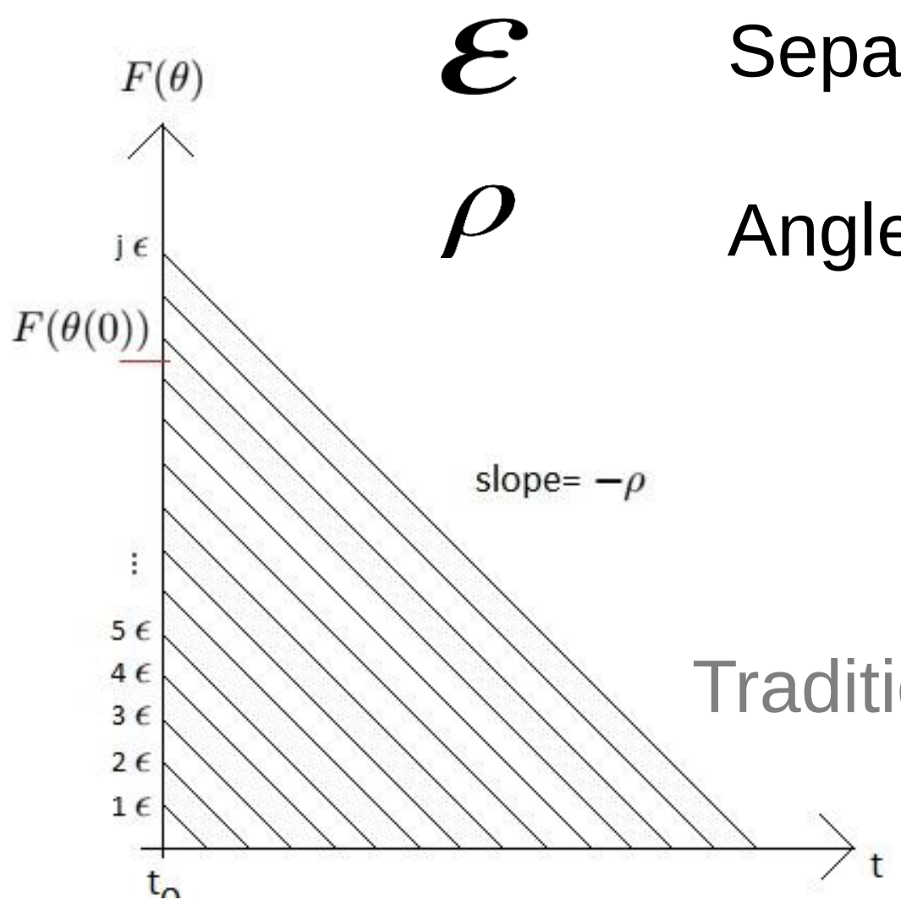
Unwanted Chattering, specific for standard sliding mode



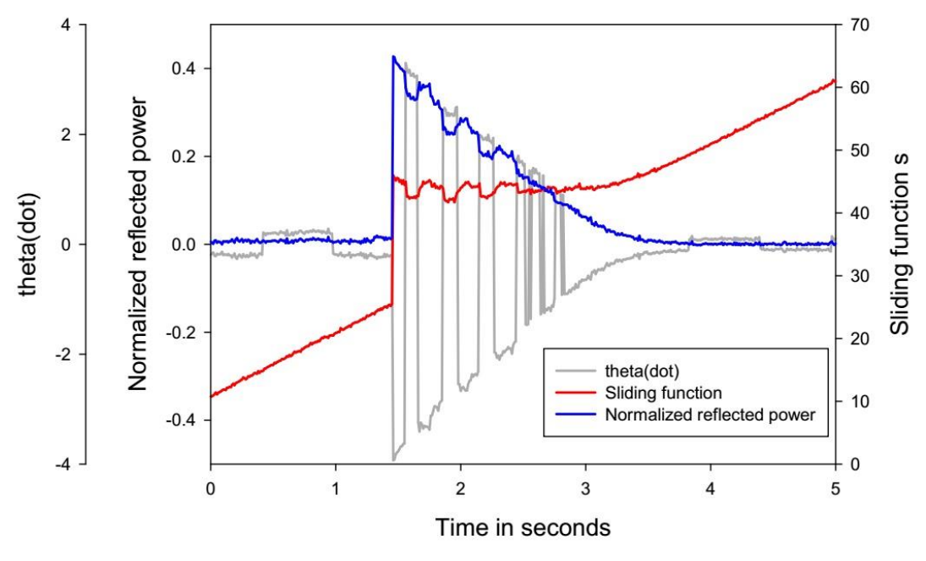


Original minimum searching algorithm:

$F(\theta)=P_r$	Reversed power to be minimized
θ	Distance to the minimum
ε	Separation between 2 modes
ρ	Angle of the modes



Traditional sliding surfaces



Measurement on room temperature resonator with chattering

Adjustments to achieve de-chattering:

Redefine the mode boundaries with C code to be folded between $-1<s<0$ and $0<s<1$

```
while (s > 1)  { s -= 2;}
while (s < -1) { s += 2;}
```

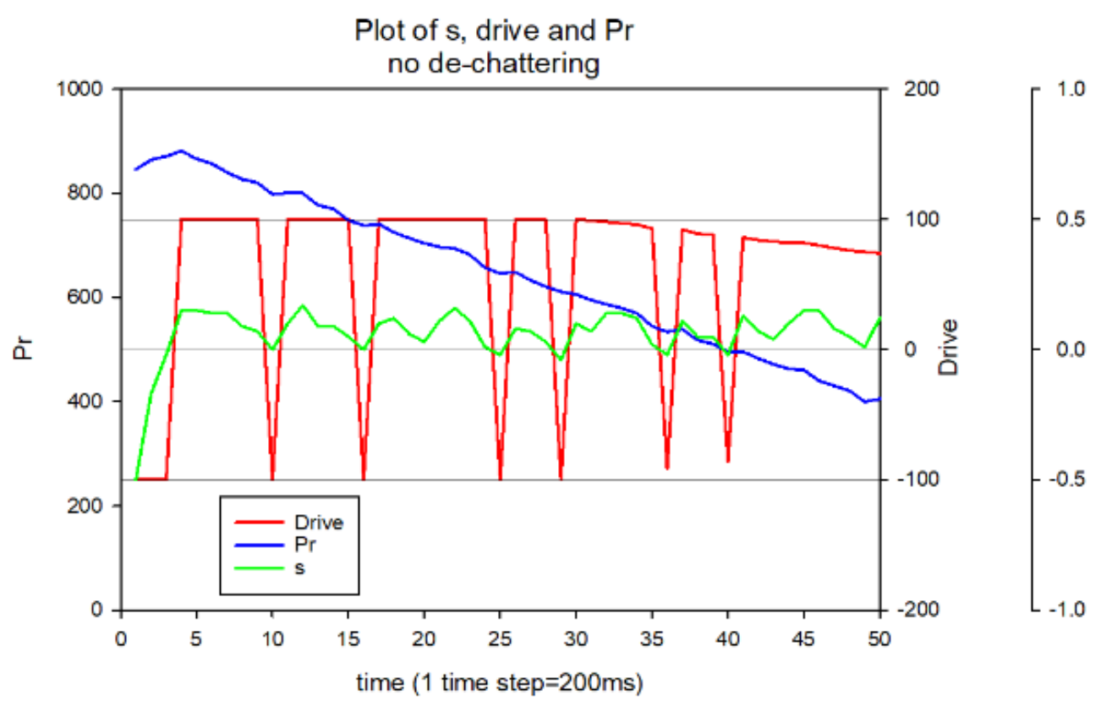
```
if (s>-0.1 && s<0) gtime -=  5*deltaTime;
if (s<0.1 && s>0)  gtime +=  5*deltaTime;
if (s>0.9)   gtime -=  5*deltaTime;
if (s<-0.9)   gtime +=  5*deltaTime;
```

Modify the sliding function to

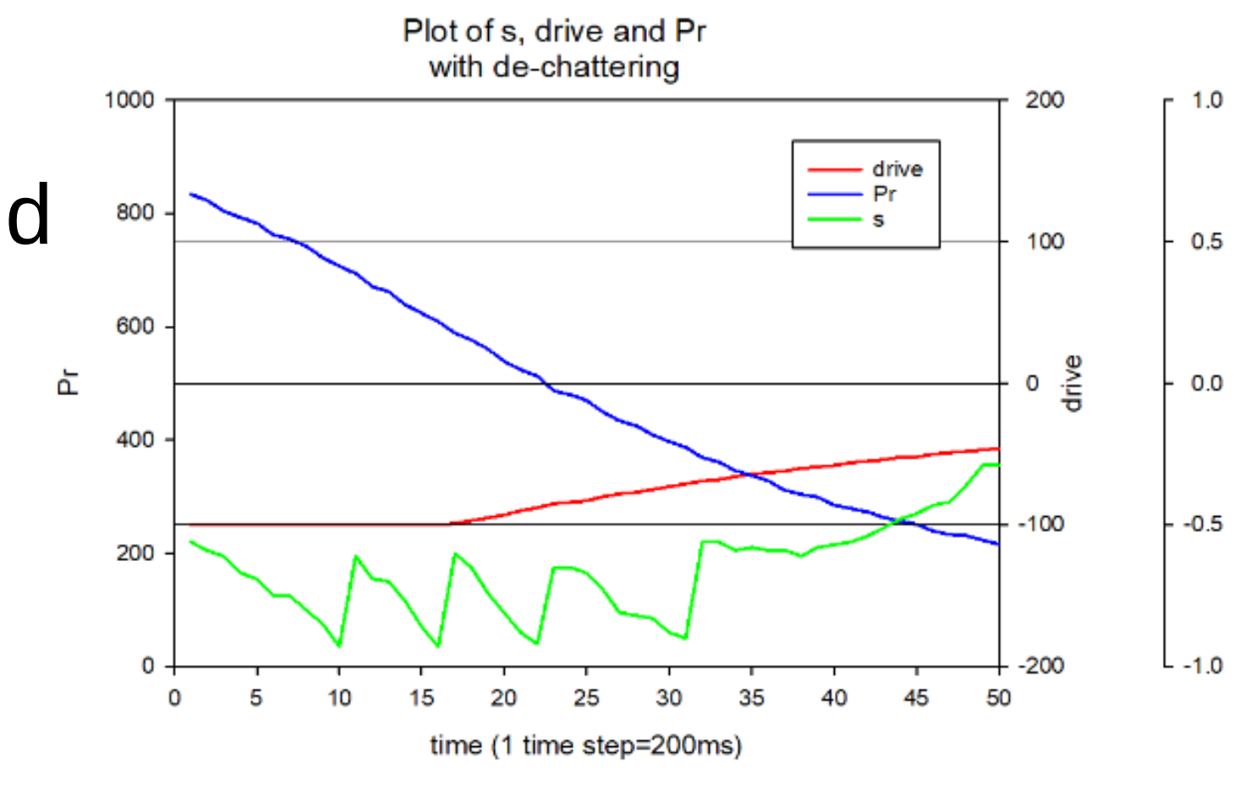
$$s(t)=\frac{1}{\varepsilon}\left[P_r-P_r(0)+\rho t\right]\pm 0.5$$

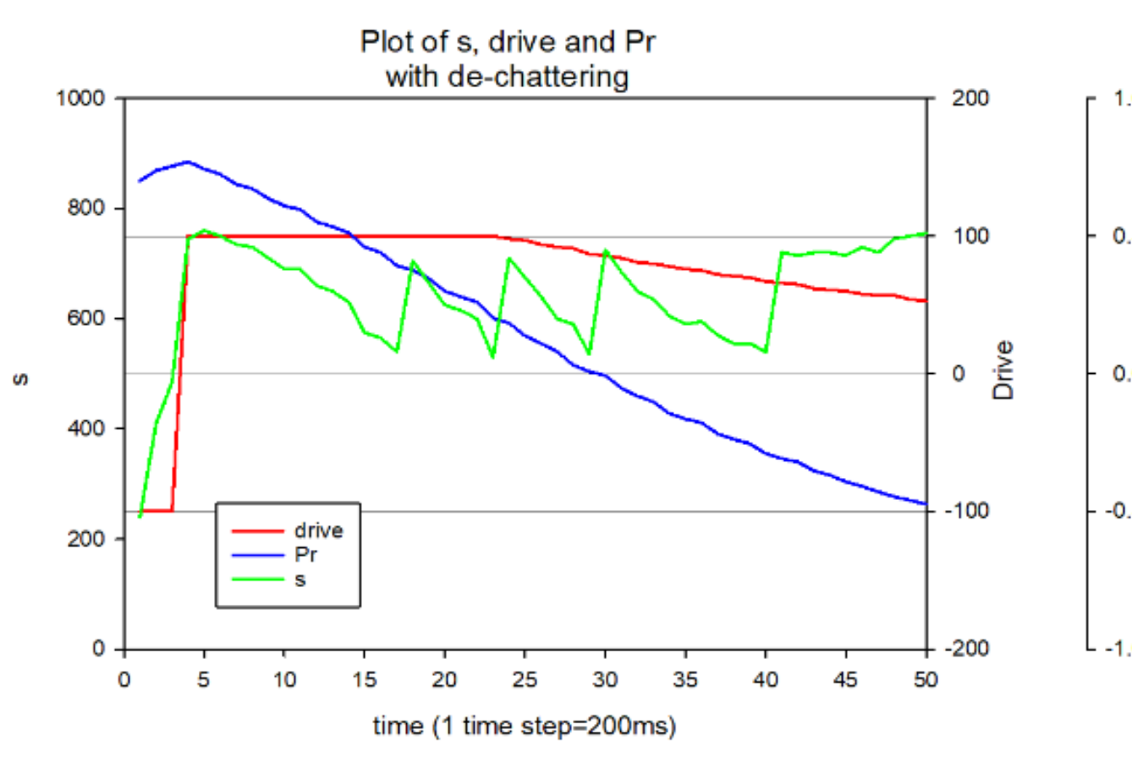
Define $t=t\pm\Delta t$ when close to the switching surface: When $s<0.1$ then $t=t+\Delta t$ and the system goes back to the center between surfaces. Surface skipping like a stone skipping on water is achieved.

With chattering



De-chattering

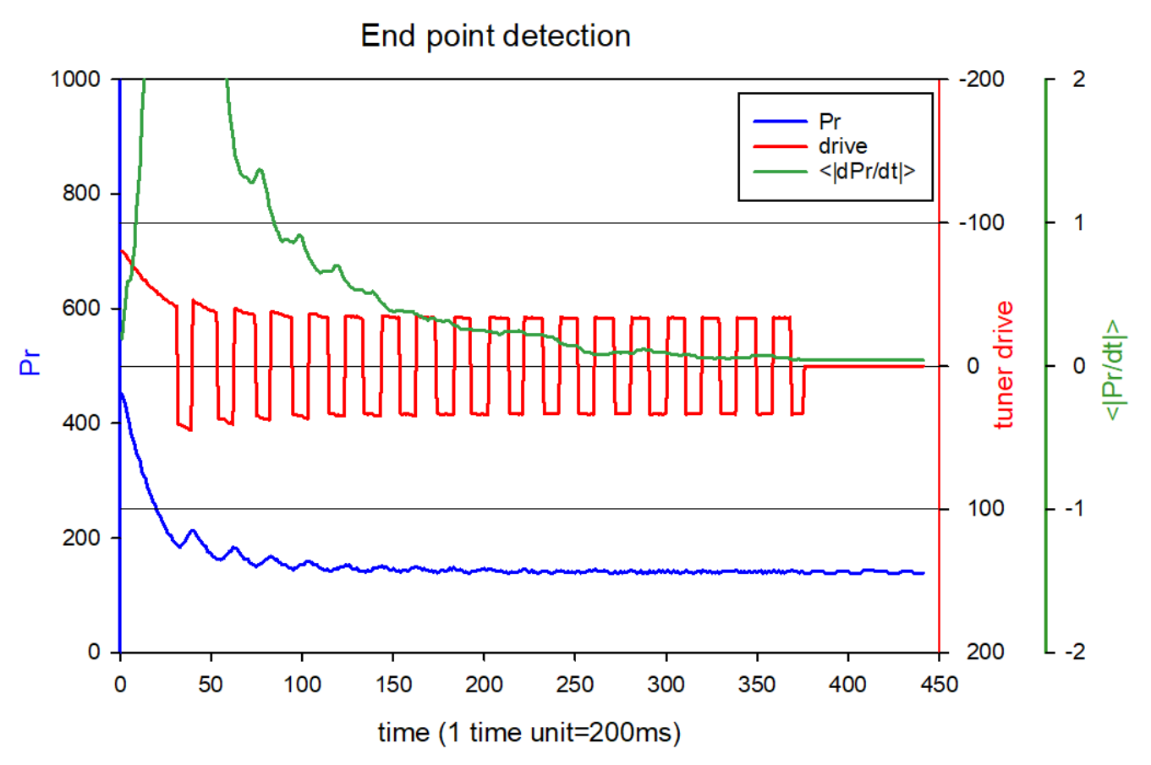




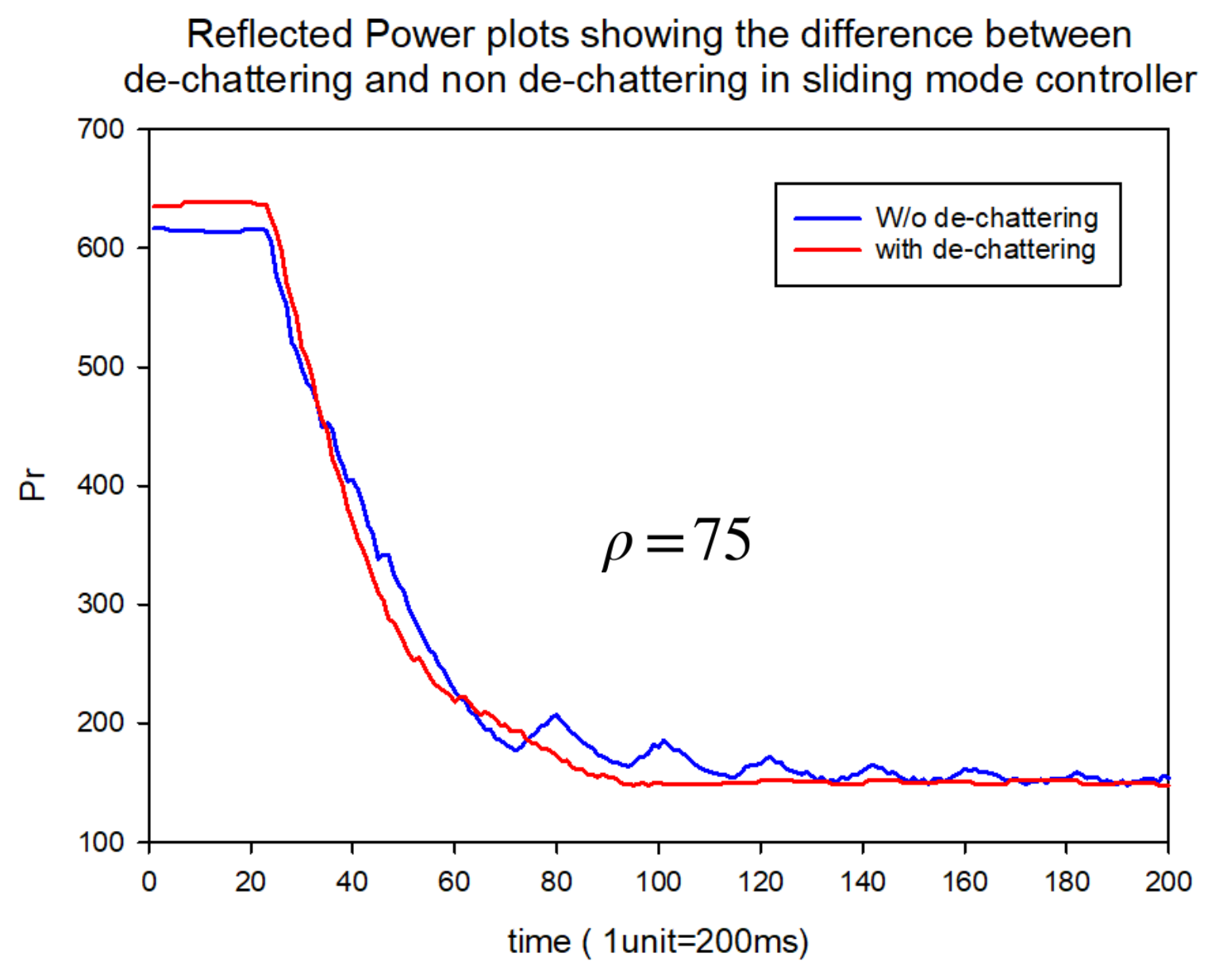
End point detection:

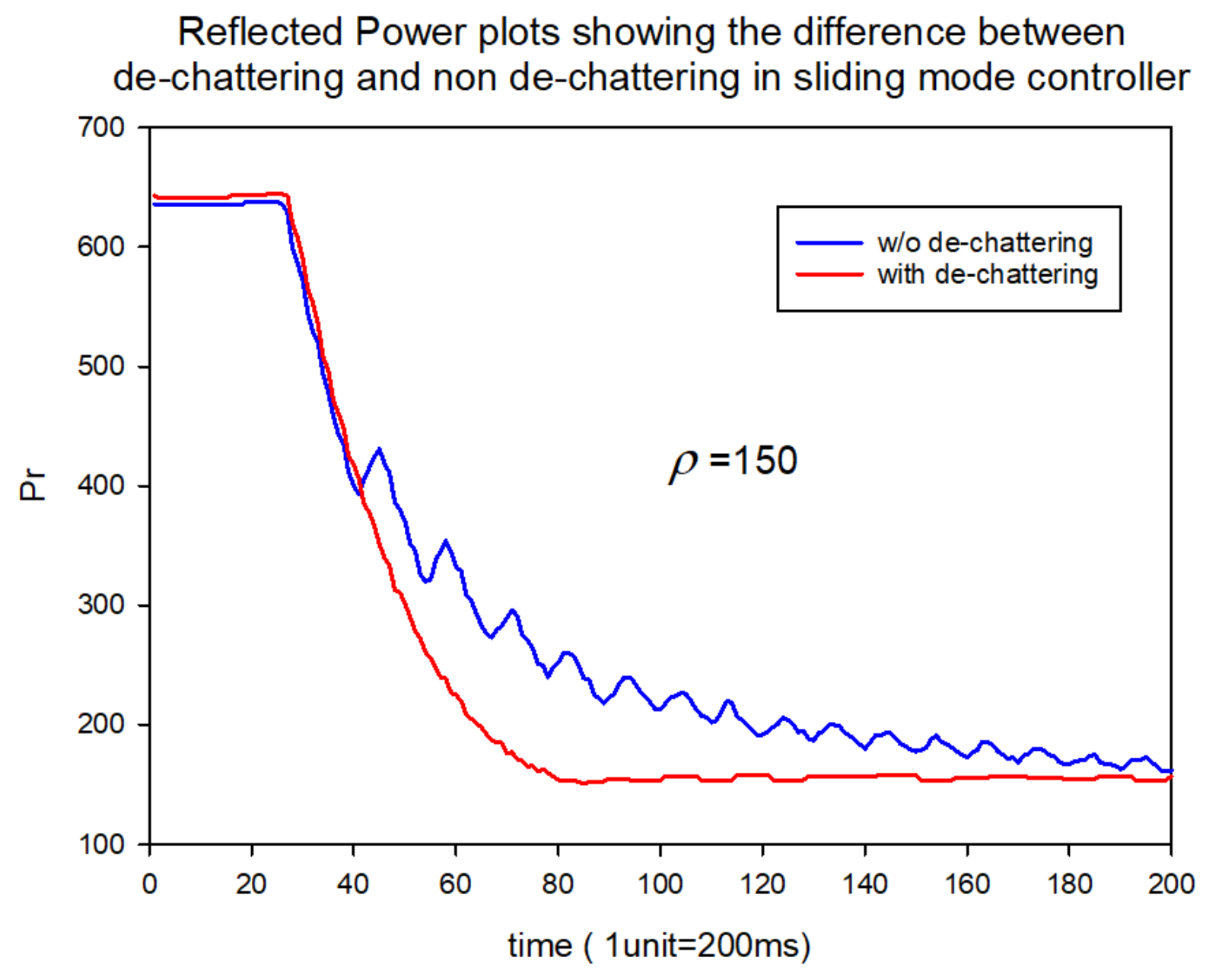
Sliding mode will only stop if the minimum reversed power equals 0 will be reached, which is not always given. End point can be detected with:

$$\left\langle\left|\frac{dP_r}{dt}\right|\right\rangle<p\approx 0.1$$



Chattering and de-chattering controller for different values of rho:





Conclusions

Modified sliding mode controllers will be used in the new ISAC-1 resonance control. Base on each system's strength and weakness, they will be used at different stages of powering up. The position preset is used during the initial stage of powering up, when the RF is not yet established and is still in pulse mode. When the RF level reaches a preset value, and switching from pulse to CW is successful, the control enters into phase alignment mode. At this stage the RF will continue to be ramping up. When phase alignment is completed the control will switch to sliding mode. When this average below the prefixed value the sliding mode will enter in a sleep mode, only to be awoken when this value is exceeded the threshold.

References

[1] R. Leewe, M. Moallem, K. Fong, "System moeling and control of resonance frequency frequency for an RF cavity using reflected power measurements",, 2014 IEEE.ASME International Conf. on Advanced Intelligent Mechantronics, 2014.

[2] Ramona Leewe, "RF Cavity Tuning Based on Reflected Power Measurements", Ph.D. Thesis, SFU, 2017.

[3] R. Leewe, Z. Shahriari, K.Fong, "Novel Scheme to Tune RF Cavities using Reflected Power", Proc. LINAC2016, E Lansing, MI, USA, 2016.

[4] J. Gulder, V. I. Utkin, "The Chattering problem in sliding mode systems", Proc. 14th Intl. Symp. Of Mathematical Theory of Networks and Systems" 2000.

[5] H. Lee, V. I. Utkin, "Chattering suppression methods in sliding mode systems", Annual Reviews in Control, Vol. 32 Issue 2, 2007, p.179-183.