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A Quench Detection Method Using RF Wave Technique

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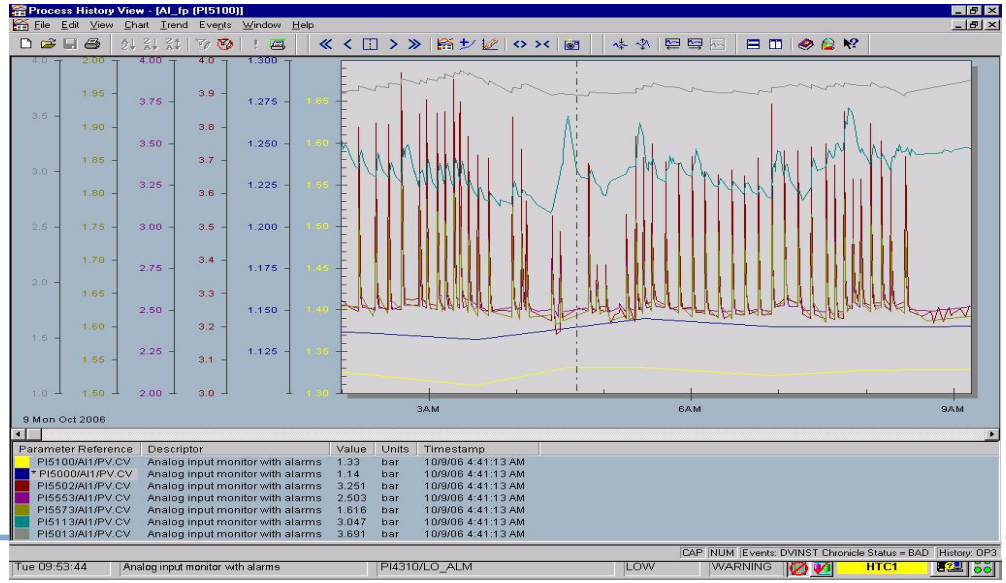
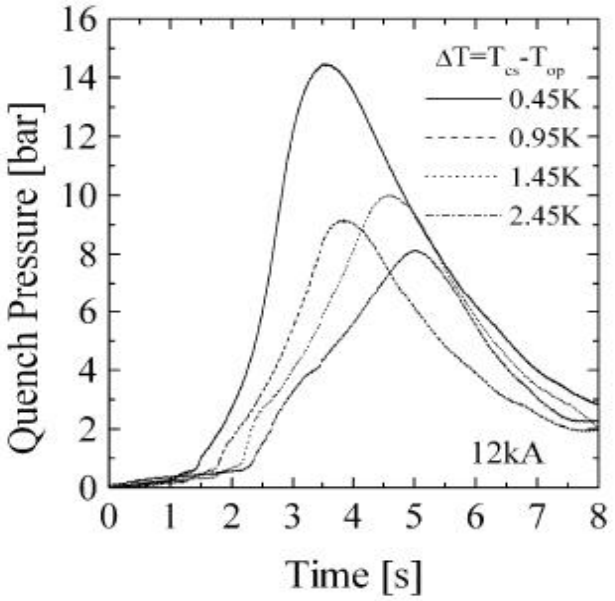
Outline

- Background
- Principle
- RF Detection System Structure
- Expermental device and proceduce
- Summary

Background

- Coil vol. ΔV; (Tore Supra)
- bridge ΔV; (LHD, HT-7, KStar)
- Co-wound ΔV (East, Kstar, ITER)
- Temp. ΔT (SMSE, T.S.)
- Pressure ΔP (East, T.S.)
- Liquid level (T.S.)
- Acoustic ΔT

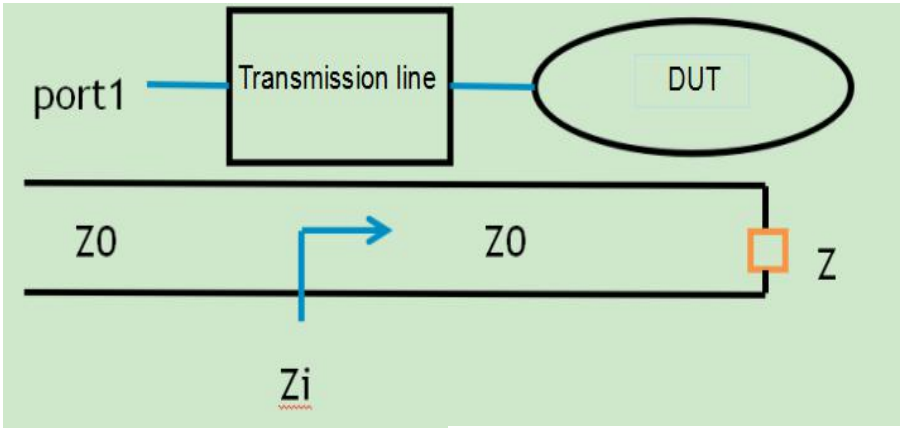




- Mainly depending on the voltage quench detection;
- Co-wound sensor is no way to repair it.

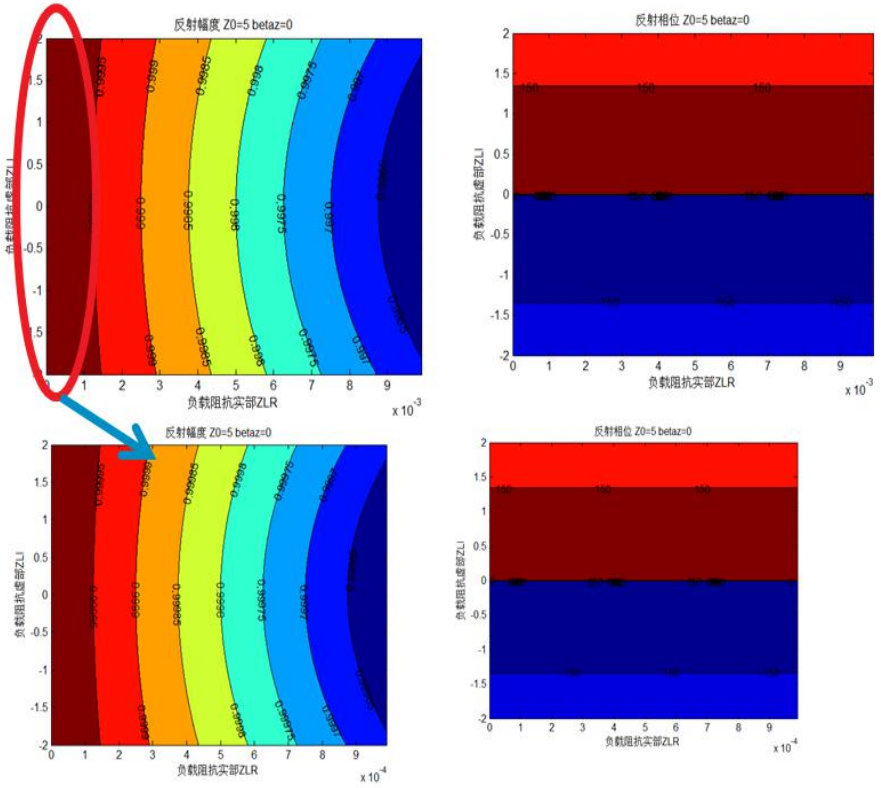
Principle

Ideal numerical modeling



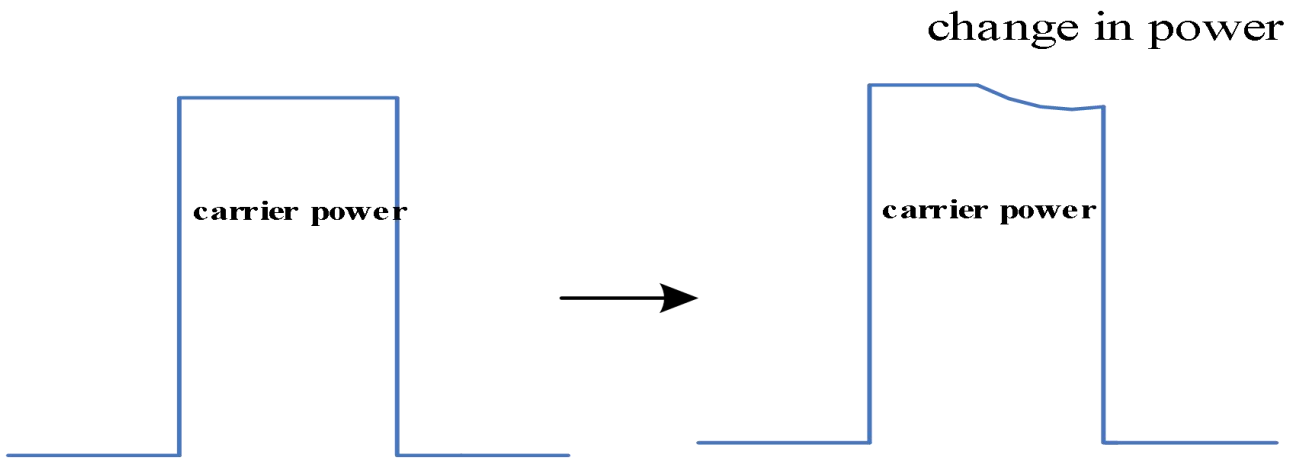
$$\Gamma = \frac{Z_{in} - Z_0}{Z_{in} + Z_0}$$

Z0 the characteristic impedance of a transmission line;
ZL the impedance of DUT
Γ reflection coefficient



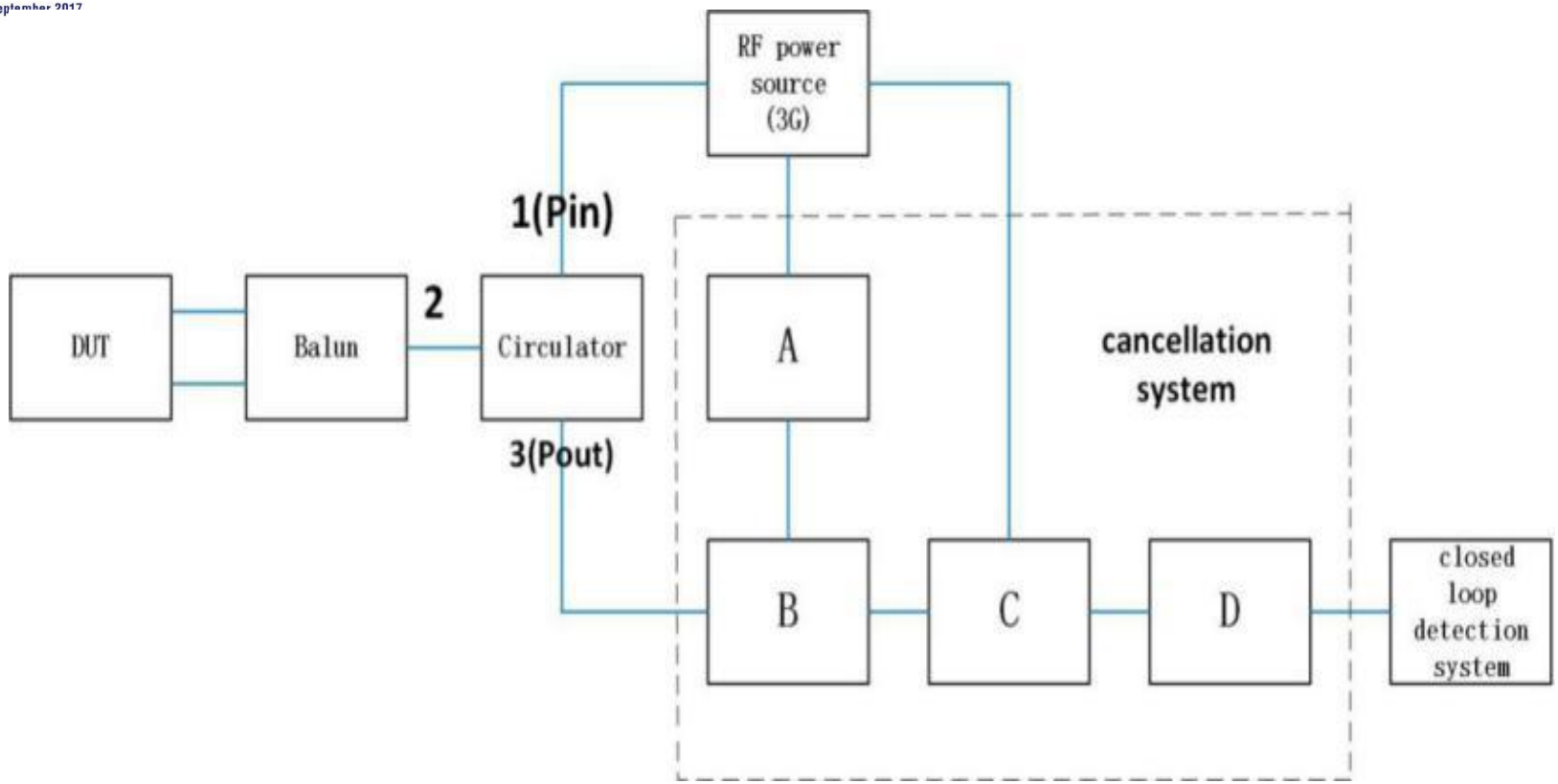
It can be observed change in power ,but hardly ignore phase change of the reflective carrier wave.

- Quenches along with Joule heating comes an increase of resistance;
- It is deemed as quench when the variable power in the carrier exceeds a certain range.



RF detection method

RF Detection System Configuration



RF detection system configuration

Note:

- DUT is Device Under Test ;
- **A.** Auxiliary system; **B.** RF ; **C.** Carrier wave c; **D.** DC cancellation

- Balun should transform the reactance opening part of DUT into short circuit on the basis of balance – unbalance transformation. (as Z=R+jX →Z=R+j0)
- The transformed load impedance is sent to the RF cancellation part when separated by the described circulator;

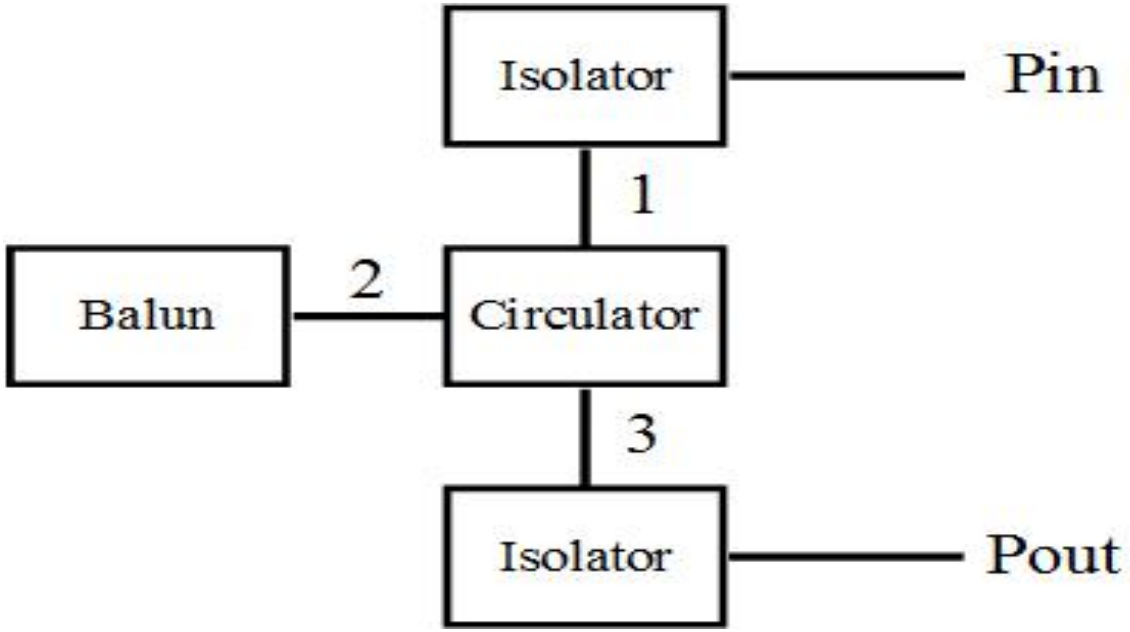
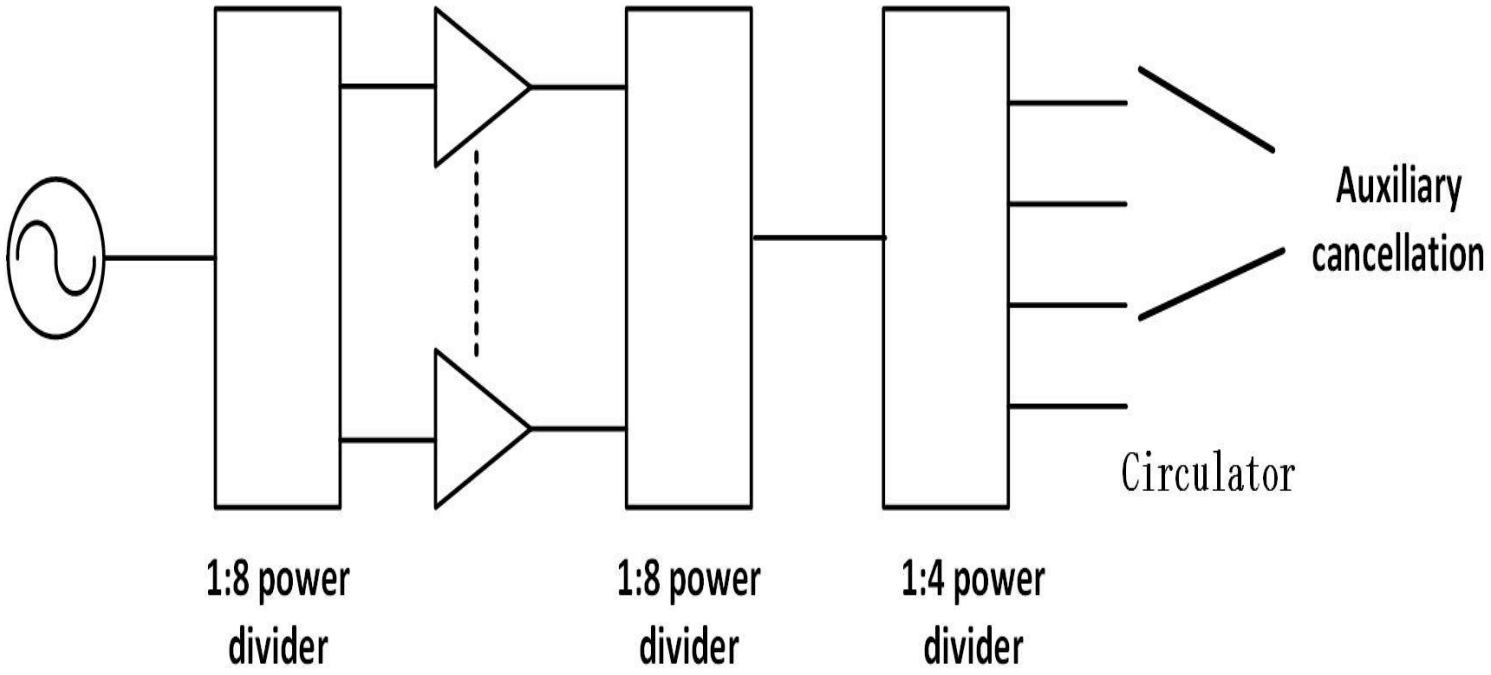
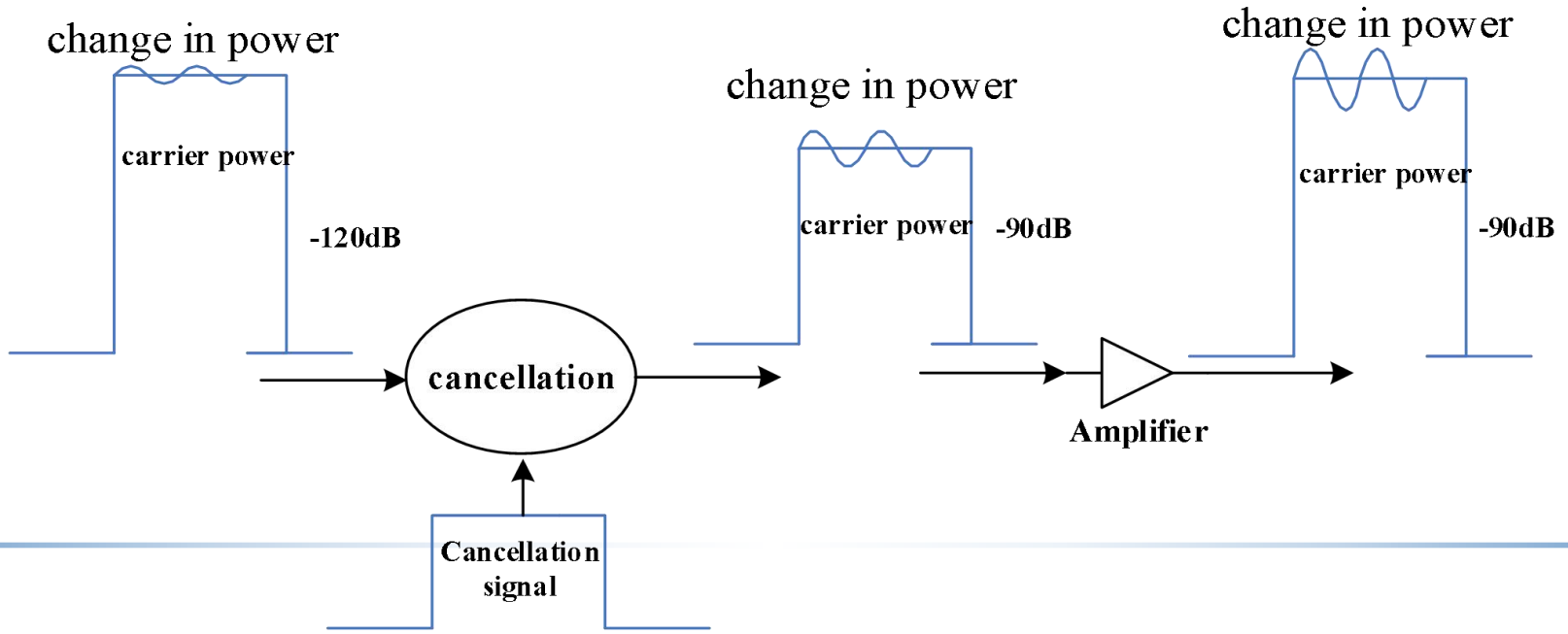


Diagram of circulator

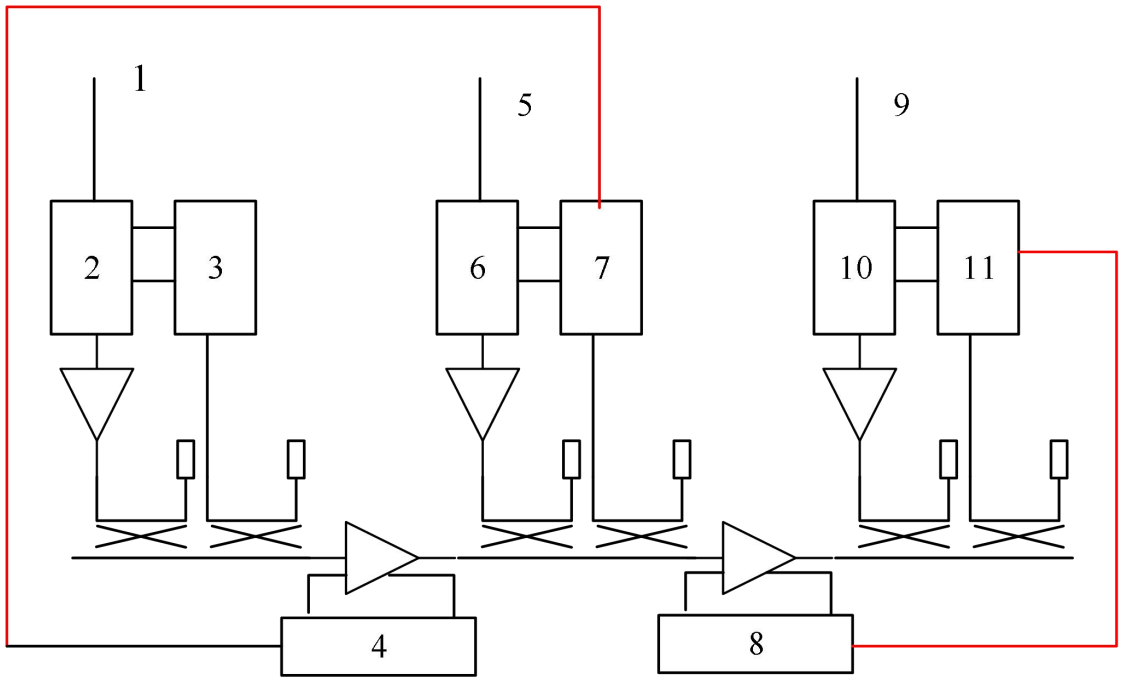
- RF power source is realized by multi-channel synthesis to ensure the stability of output power (3G HZ)



- The cancellation system receives inherent cancellation signal to cancel the invariant part in the carrier and amplify the residual carrier and variable power;
- The amplified signal passes the carrier cancellation part, which converts the signal received to variable DC voltage signal.
- Such signal accepts further cancellation treatment by DC cancellation part.



- The treated signal is sent to the closed loop detection system, which realizes the detection of variable component and the output of results.



Note:
1,5,9 auxiliary cancellation ; 2,6,10 phase control
3,7,11 cancellation loop ; 4,8 Phase stability monitor

Main Detection principles

mixing

$U_{dect}=[A+Bf(t)]*\cos(\omega t+\Delta\varphi)$ ⇒ $1/2\,[A+Bf(t)]*\cos(\Delta\varphi)+1/2[A+Bf(t)]*\cos(2\omega t+\Delta\varphi)$

filter

$[A+Bf(t)]*\cos(\Delta\varphi)$ ⇒ $Udect\approx A+Bf(t)$

$\cos(\Delta\varphi)\approx 1$

Namely:

A the base wave component ;

B a power changes of the reflected wave

Δφ is the phase change component;

f(t) is the change of power;

√Filter circuit is to realize the filtering of 2ωt ;

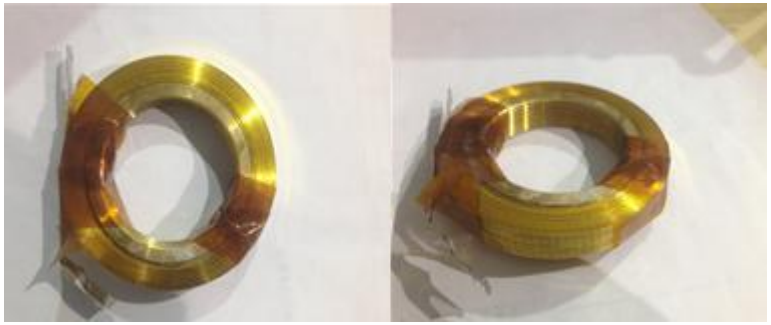
√Phase conversion components are below 0.1° , thus cos(Δφ) is around 1;

√System change components are divided into DC component and slowly varying component.

No quench $U_{dect}=A$ (namely $Bf(t)\approx 0$);

if case of quench $U_{dect}=A+Bf(t)$;

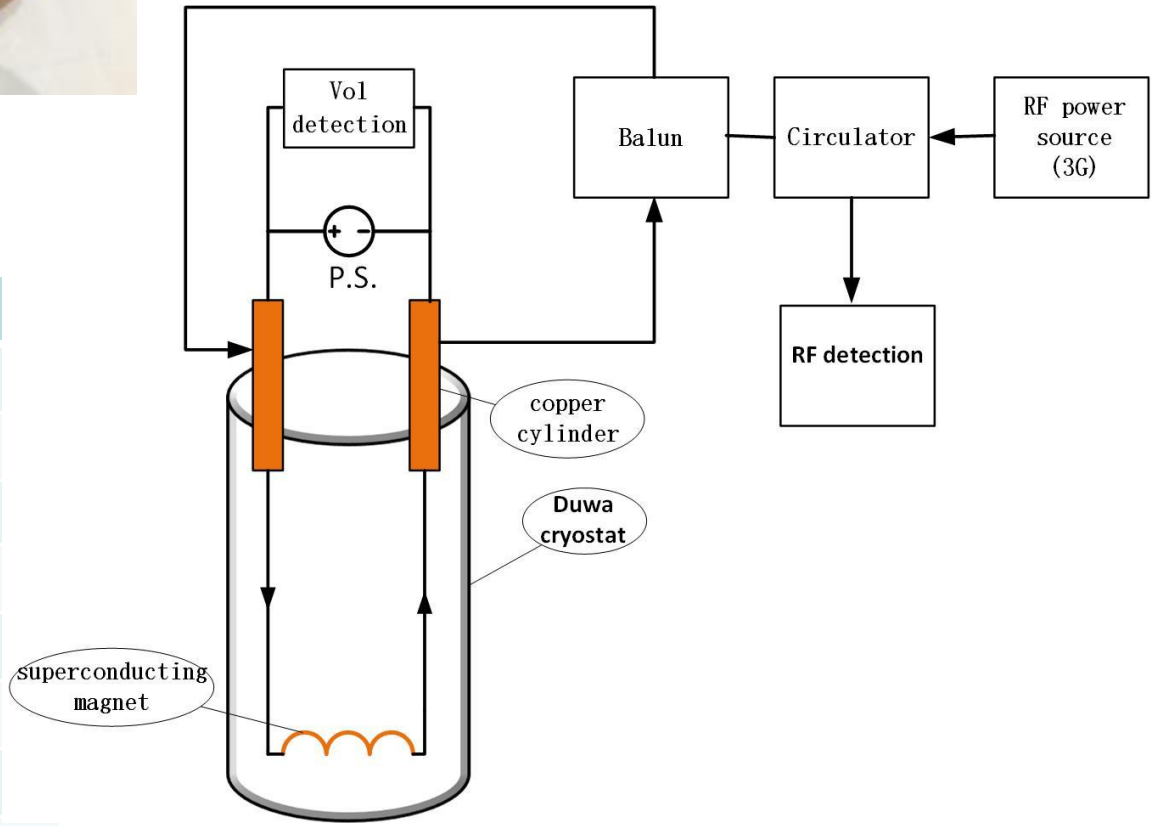
Expermental device and proceduce



YBCO experimental magnet

the specification of magnet

Wires	YBCO(Shanghai tape)
Inner dia.[mm]	60.4
Outer dia.[mm]	70.66
Height[mm]	9.8
length [m]	16
No.of turns	38
Inductance[mH]	0.141
Ic	100A at 77k self-field
Cooling mode	immersing the whole assembly in liquid helium



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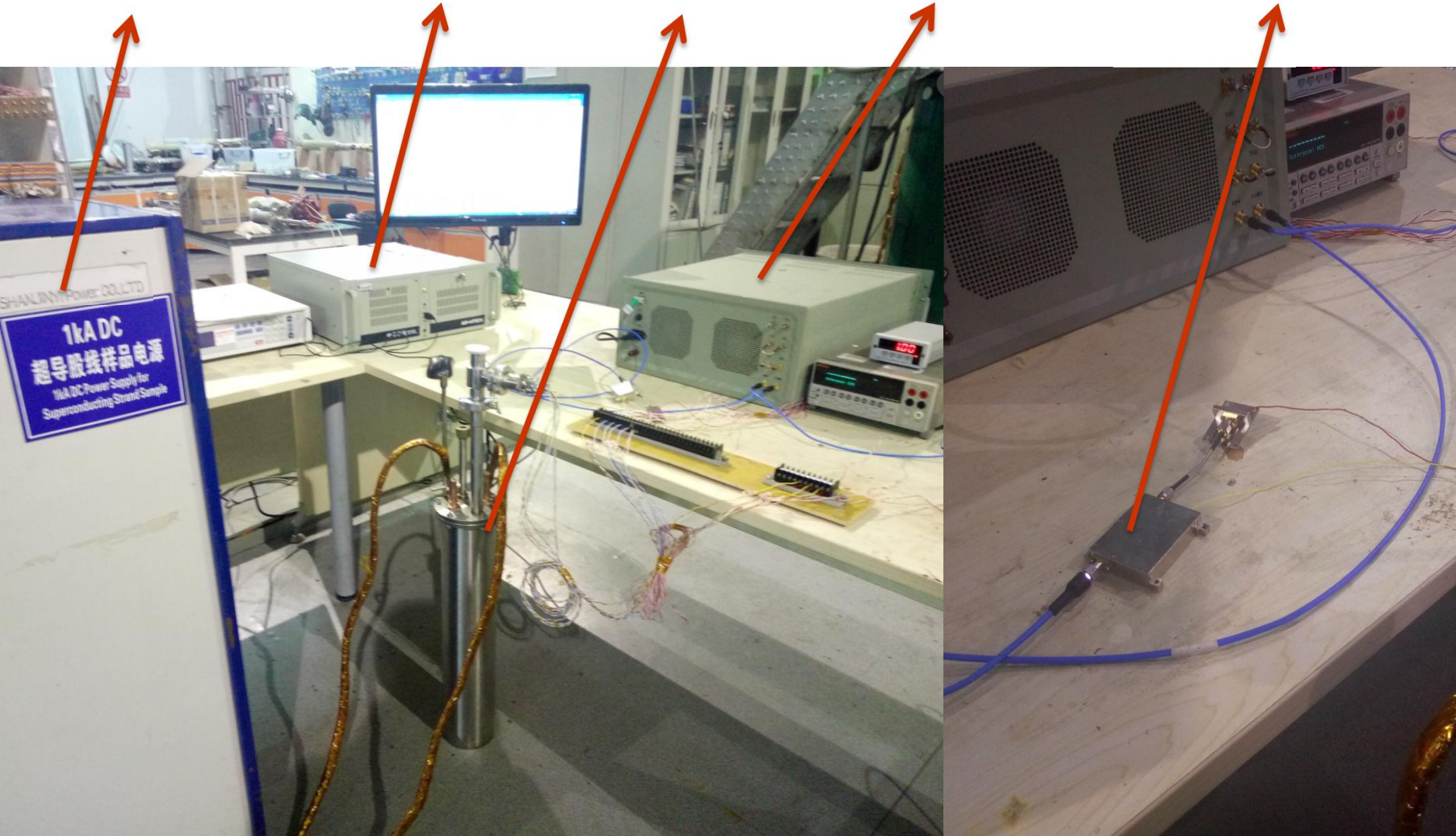
Expermental System Setup



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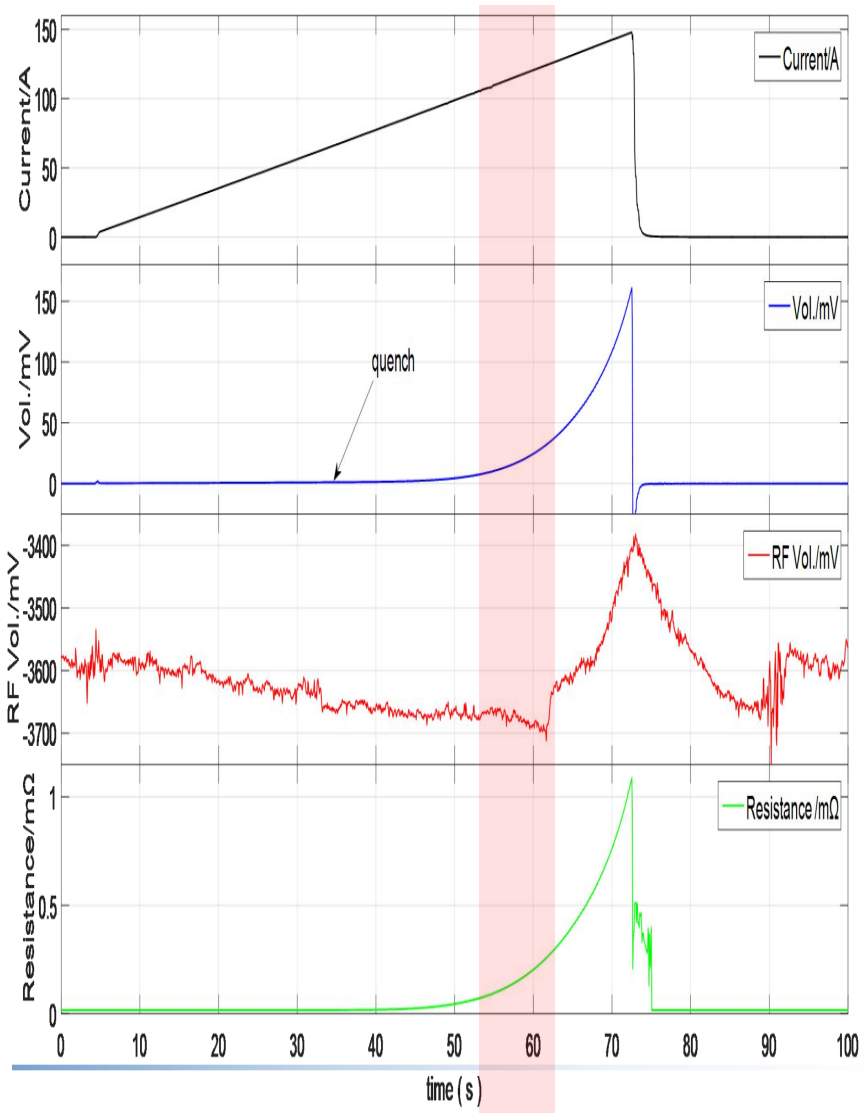
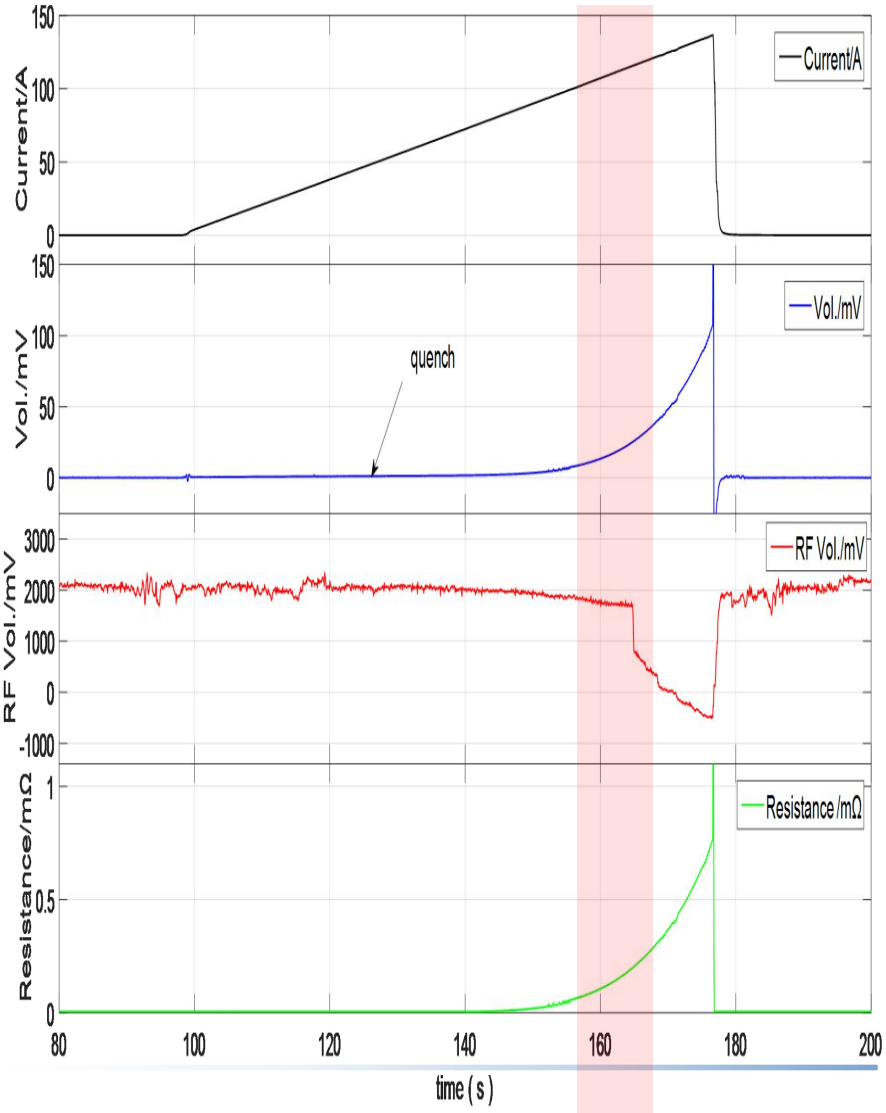
Test results





Summary

- A quench can be detected using RF detection and the precision can be around 0.1-0.2 mΩ .
- Compared with voltage detection, the RF system only has obvious response after the start of quench and before the resistance change reaches a value, but easy maintenance.
- There still exist many problems such as the system response , anti-interference performance,precision etc...

Thanks for your attention

Your suggestions and commends will be appreciated