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MICROPHONICS STUDY OF ARIEL ACM1 TWO CAVITIES CRYOMODULE

Yanyun Ma

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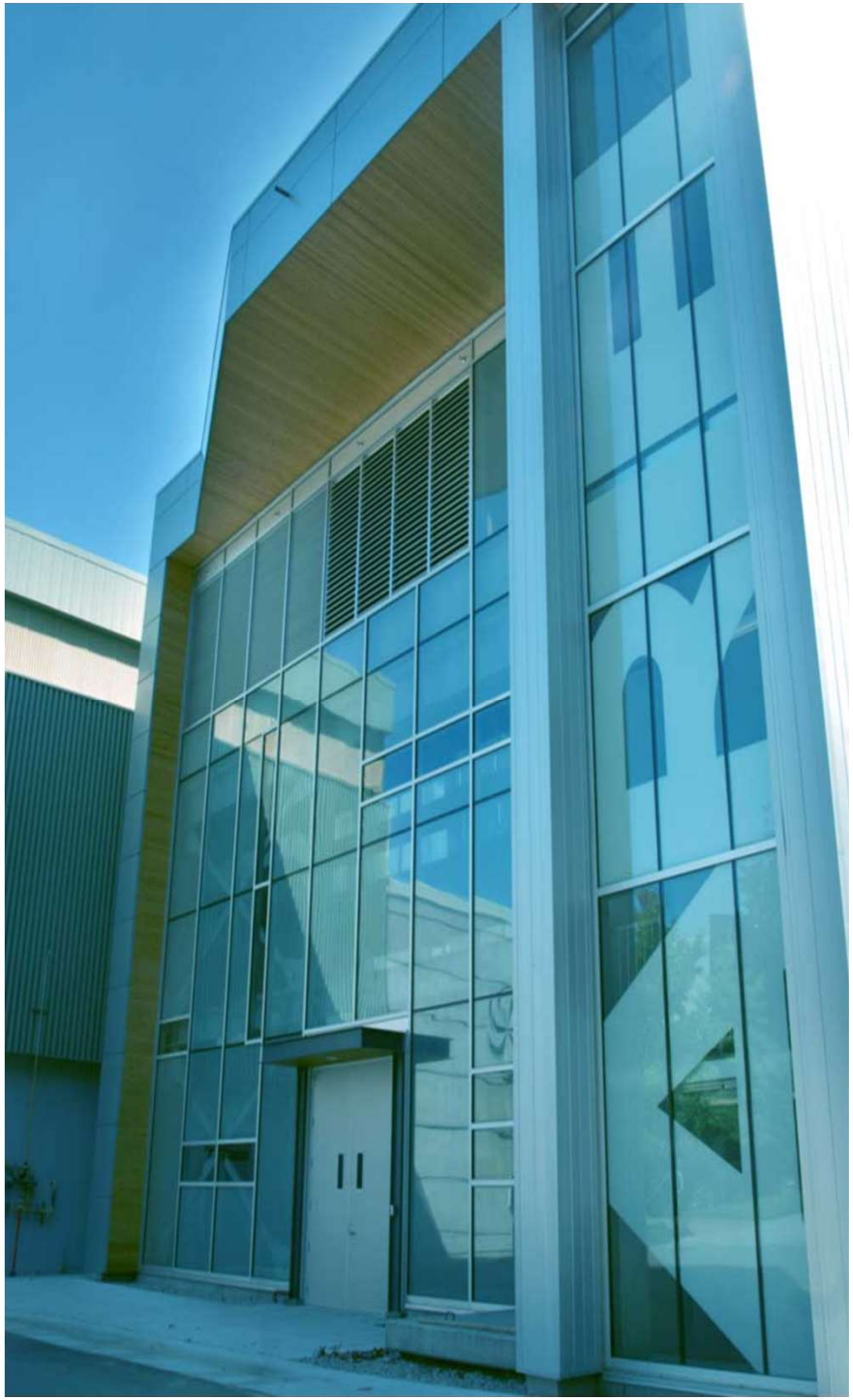


2018-10-24

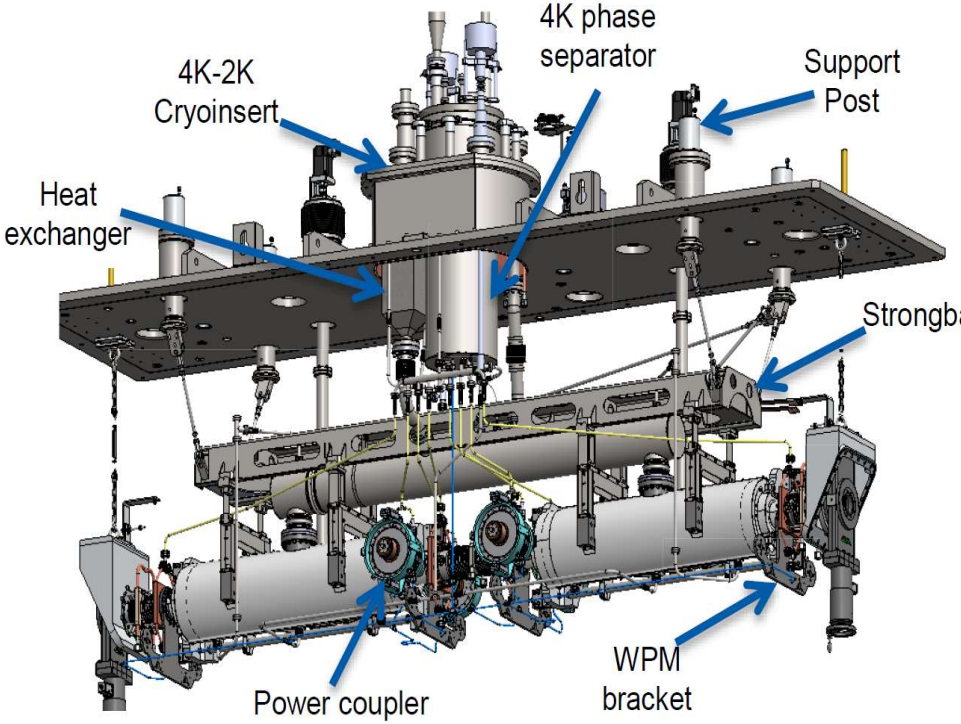
Discovery, accelerated

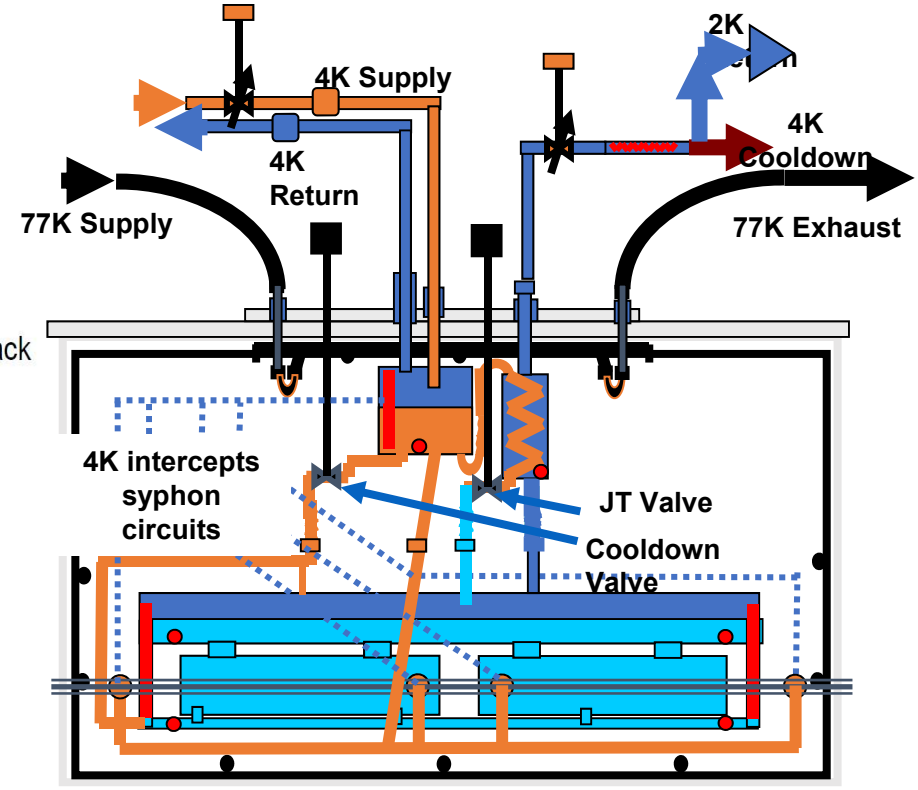
Outline

1. Overview of ACM1
2. Pondermotive effect and RF noise
3. LN system disturbance
4. Microphonics source searching
5. Water system investigation
6. Discussion

1.Overview of ACM1

ACM1 assemble

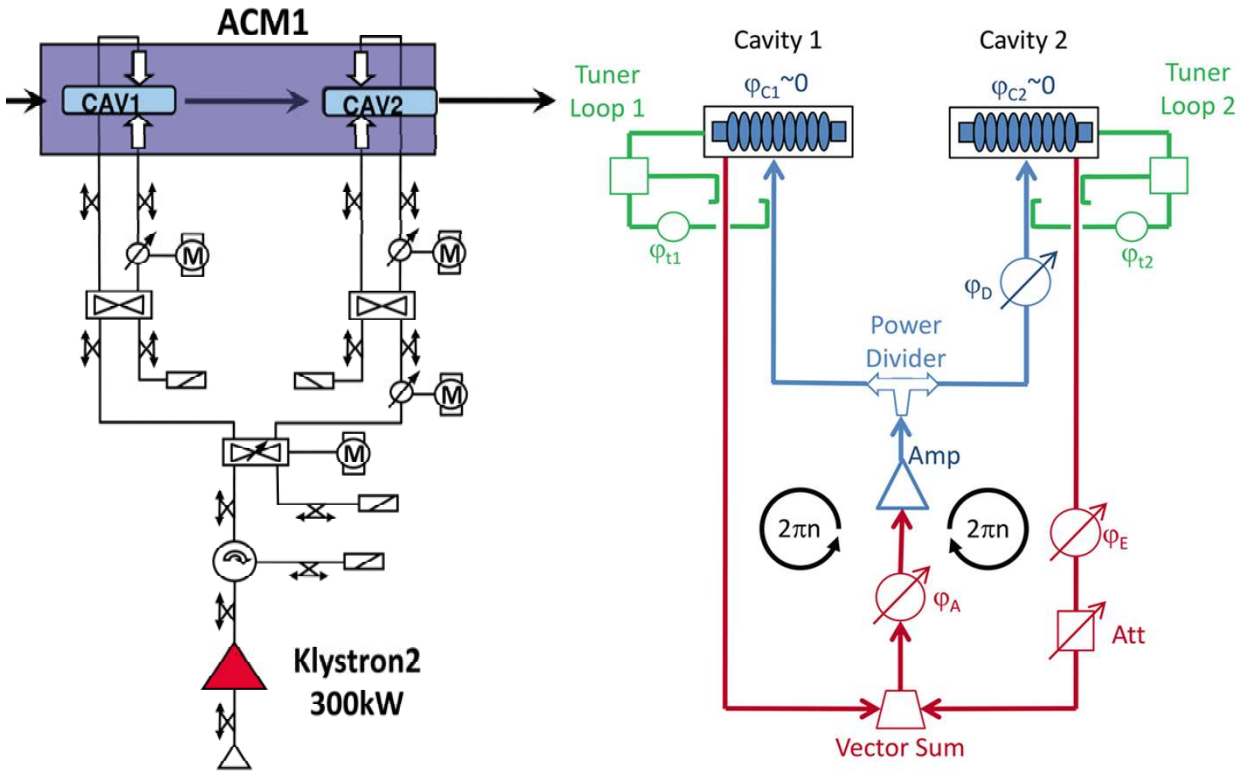




- An unique box cryomodule with a top-loading cold mass
- Scissor tuner with warm motor
- Two layers of mu metal – warm and cold
- WPM based alignment
- Stainless steel ribbed tank with hatches for access

- 4K intercepts cooled by siphon circuit from 4K reservoir ; Cooldown circuit for initial cooling ; LN2 cooled thermal shield
- 4K/2K heat exchanger unit with JT valve on board

ACM1 RF system overview



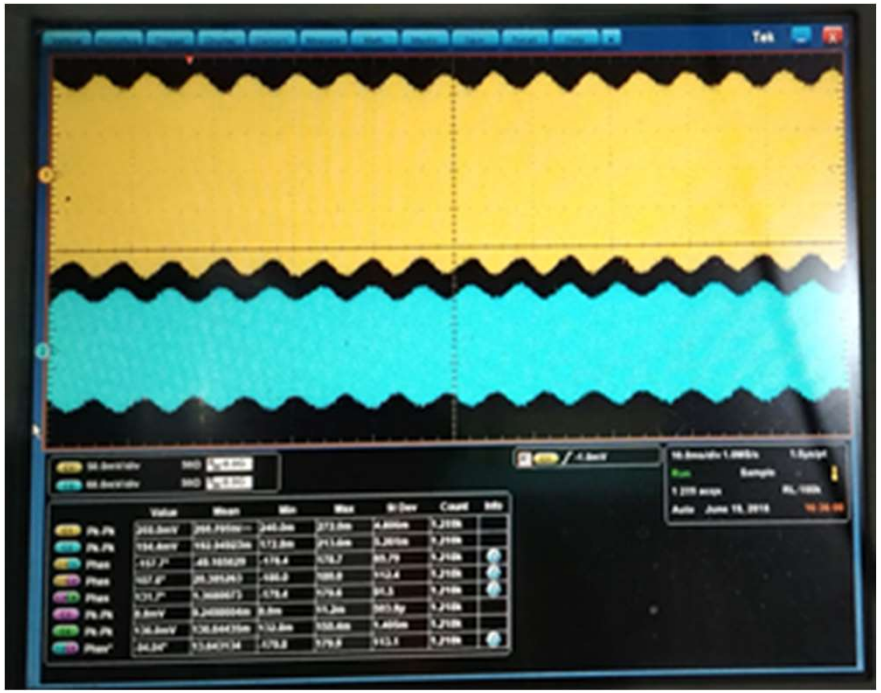
- ACM1
  - Two cavities
  - Two tuners
  - One source
- vector-sum control of the two cavity SEL PLL
  - Each cavity is tuned separately with SEL then combined in a single loop
- The loop phases for both cavities will be kept to a multiple of 2π

Two ACM1 cavities are driven by a single klystron with vector-sum control of the two cavity SEL PLL.

Yanyun Ma *et al.*, "First RF test results of two-cavities accelerating cryomodule for ARIEL e-LINAC at TRIUMF", in Proc. IPAC'18, Vancouver, BC, Canada, paper THPMK090, pp. 4512-4515.
Ken Fong *et al.*, "TUNERS ALIGNMENT ON TWO 9-CELL CAVITIES WITH SINGLE AMPLIFIER UNDER SELF-EXCITED LOOP" in Proc. IPAC'18, Vancouver, BC, Canada, paper THPMK096, pp.4527-4529

2. Pondermotive effect and RF noise

Pondermotive effect



Oscillation in counterphase under vector-sum regulations. Yellow: 1st cavity pickup signal; Green : 2nd cavity pickup signal.

No gradient regulation for each cavity

Individual tuner loops are established with respect to the established reference phase

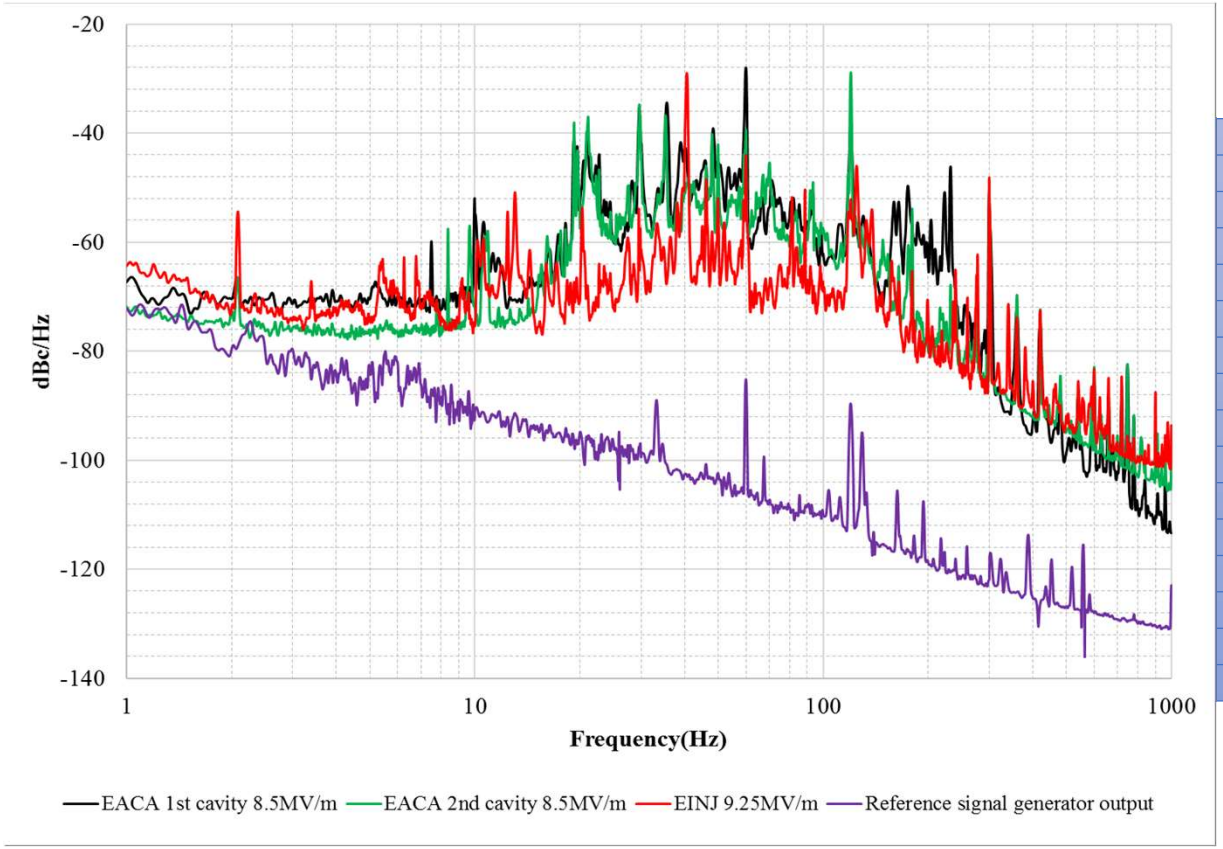
Microphonics excite mechanical resonances in one cavity, coupling to the other cavity via vector-sum regulation.

The modulations of the RF field between the two cavities can drive a ponderomotive instability through Lorentz force detuning.

The threshold for excitation of this instability is impacted both by ambient microphonic noise and the precise settings of the two cavity phase loops.

The coupled oscillation deteriorates the e-Linac final energy stability.

Phase noise spectrum of each cavity



ACM1 was under single cavity mode with low proportion gain

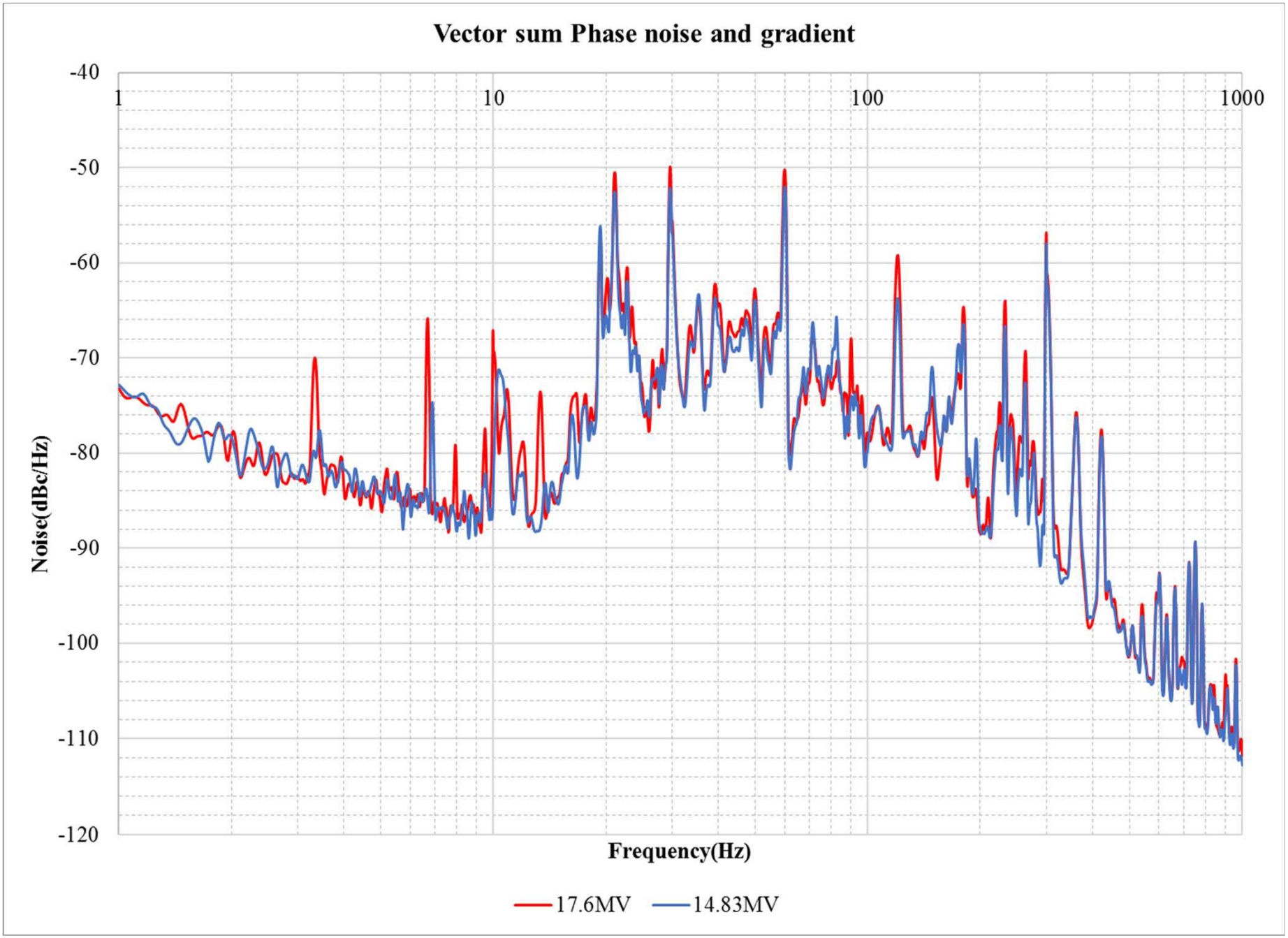
f(Hz)	BW(Hz)	Q
59.97	0.62	96.73
119.96	1.8	66.64
35.56	0.62	57.36
48.30	0.8	60.37
29.65	0.35	84.72
232.17	2.02	114.93
39.02	0.98	39.82
175.13	3.05	57.42
223.27	2.88	77.52
299.90	1.41	212.7
19.24	0.21	91.65
21.01	0.4	52.53
159.65	2.78	57.42
19.64	0.23	85.40
9.98	0.05	199.73

f(Hz)	BW(Hz)	Q
120.04	0.89	135.35
35.27	0.38	93.68
60.02	0.30	199.86
29.66	0.60	49.43
47.99	0.30	159.99
49.90	0.30	166.32
19.26	0.19	100.647
21.13	0.32	66.03
300.10	0.60	498.33
19.70	0.10	197.05
180.06	0.97	185.78
22.73	0.10	227.34
175.61	2.40	73.17
360.11	2.85	126.57
164.72	1.2	137.27

Spurious List

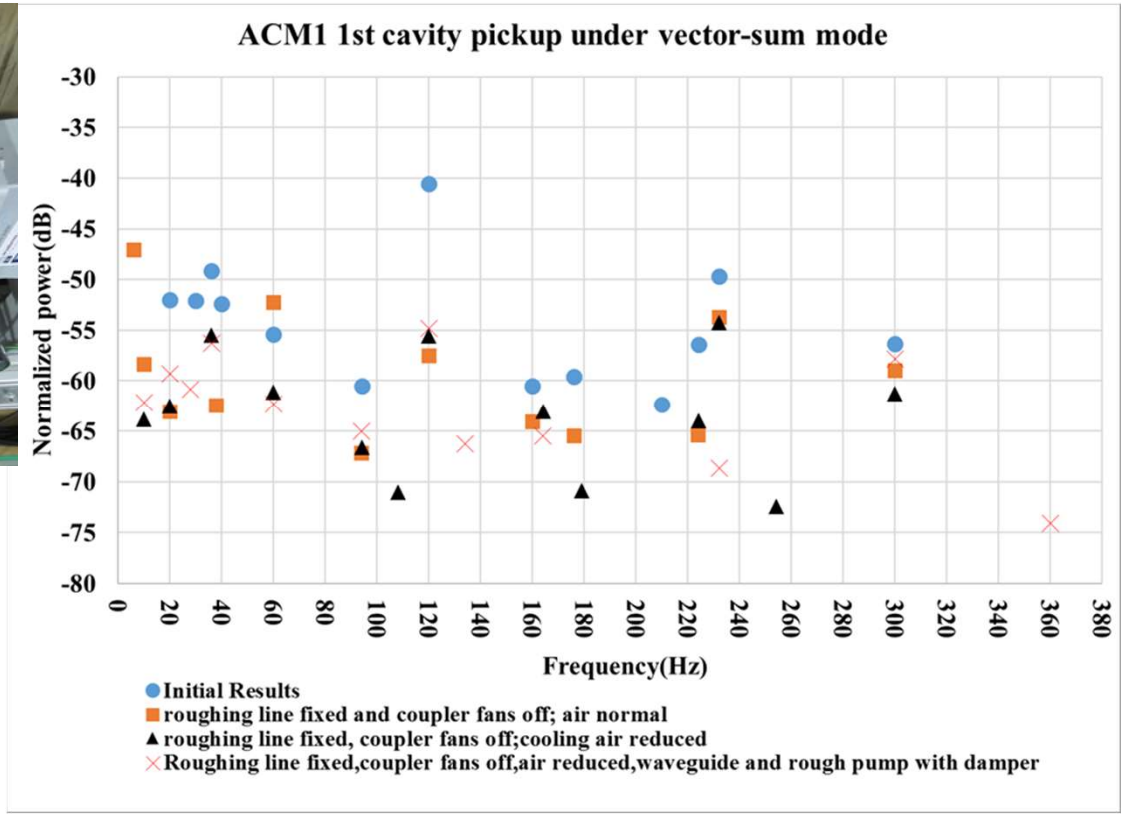
Equipment used: R&S®FSWP26

Noise hump (10~ 400Hz) in each pickup signal indicates the noise sources are universal for 2 cryomodules and all three cavities



The noise become stronger with higher gradient

Vibration damping during beam test

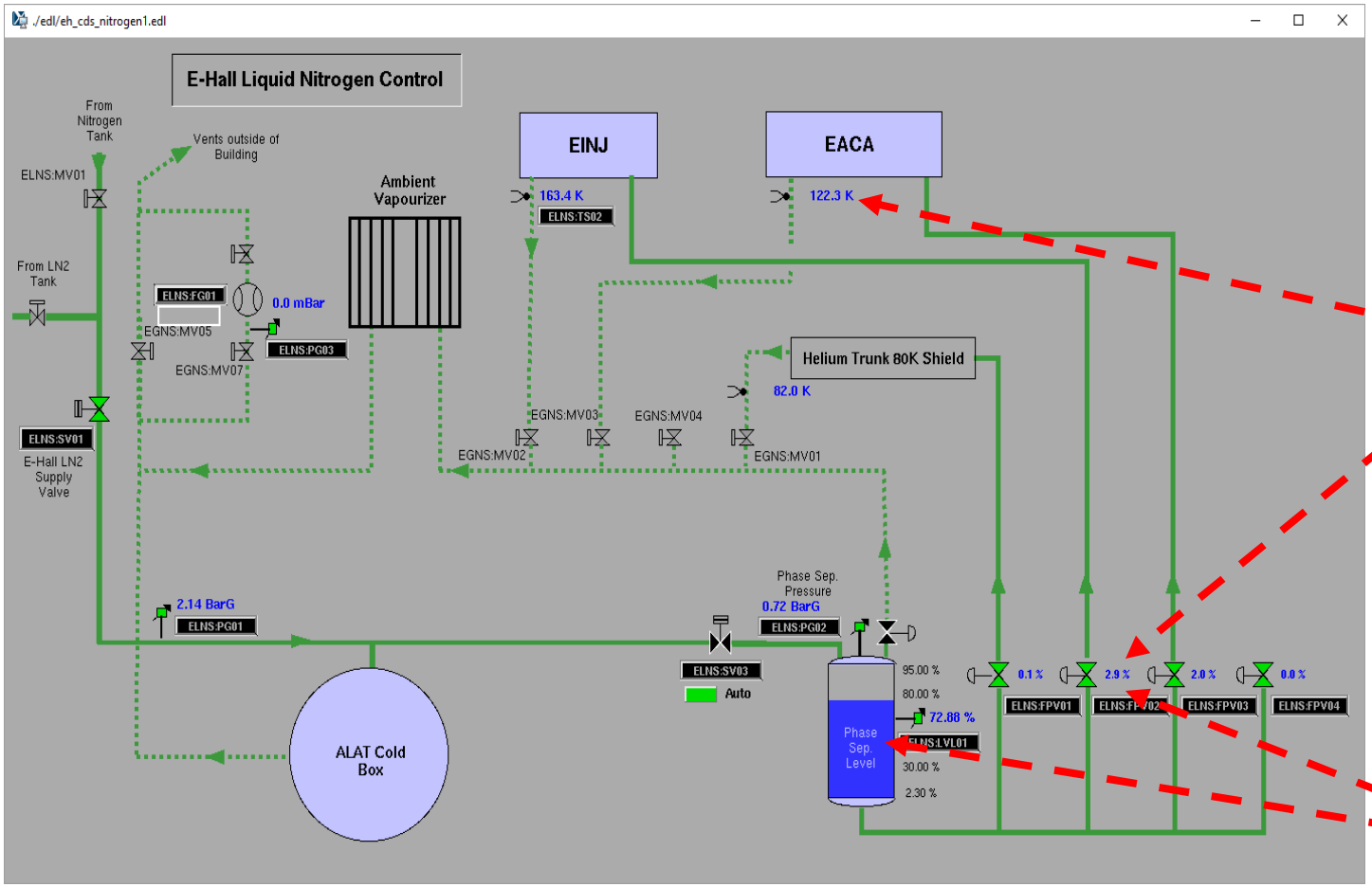


- Fixing roughing bellows and turn off cooling fans
  - most noise peaks are reduced especially the 120Hz peak
- Reduced the cooling air flow
  - only 3 noise peaks higher than -60dB
- Temporary damping of the waveguide and adding damping pad under roughing pump
  - the 232Hz noise peak reduced about -10dB

Measured at same setpoint

3. LN system disturbance

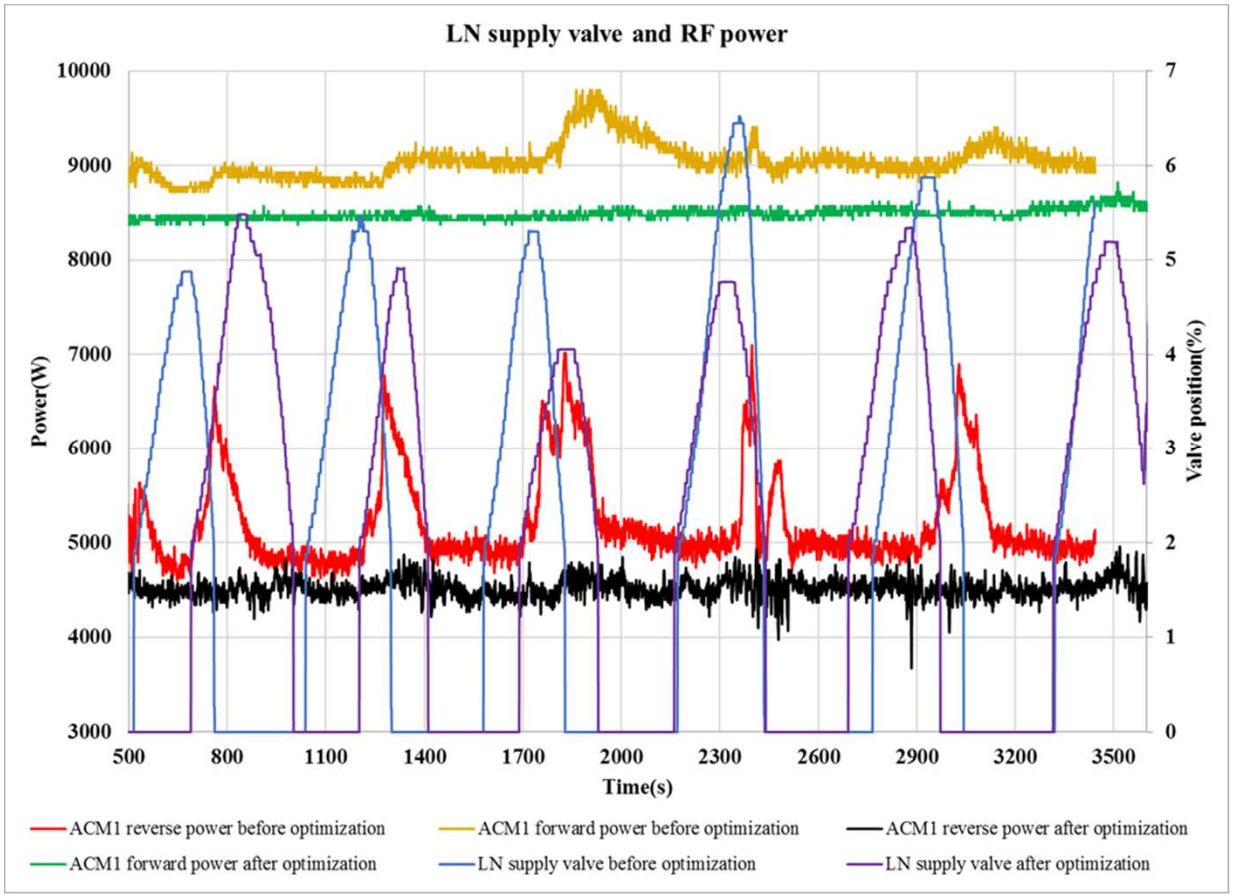
E-linac LN system



The supply valve is controlled by exhaust temperature and not regulated well. When valve closed the line between supply valve and CM will be warmed up.

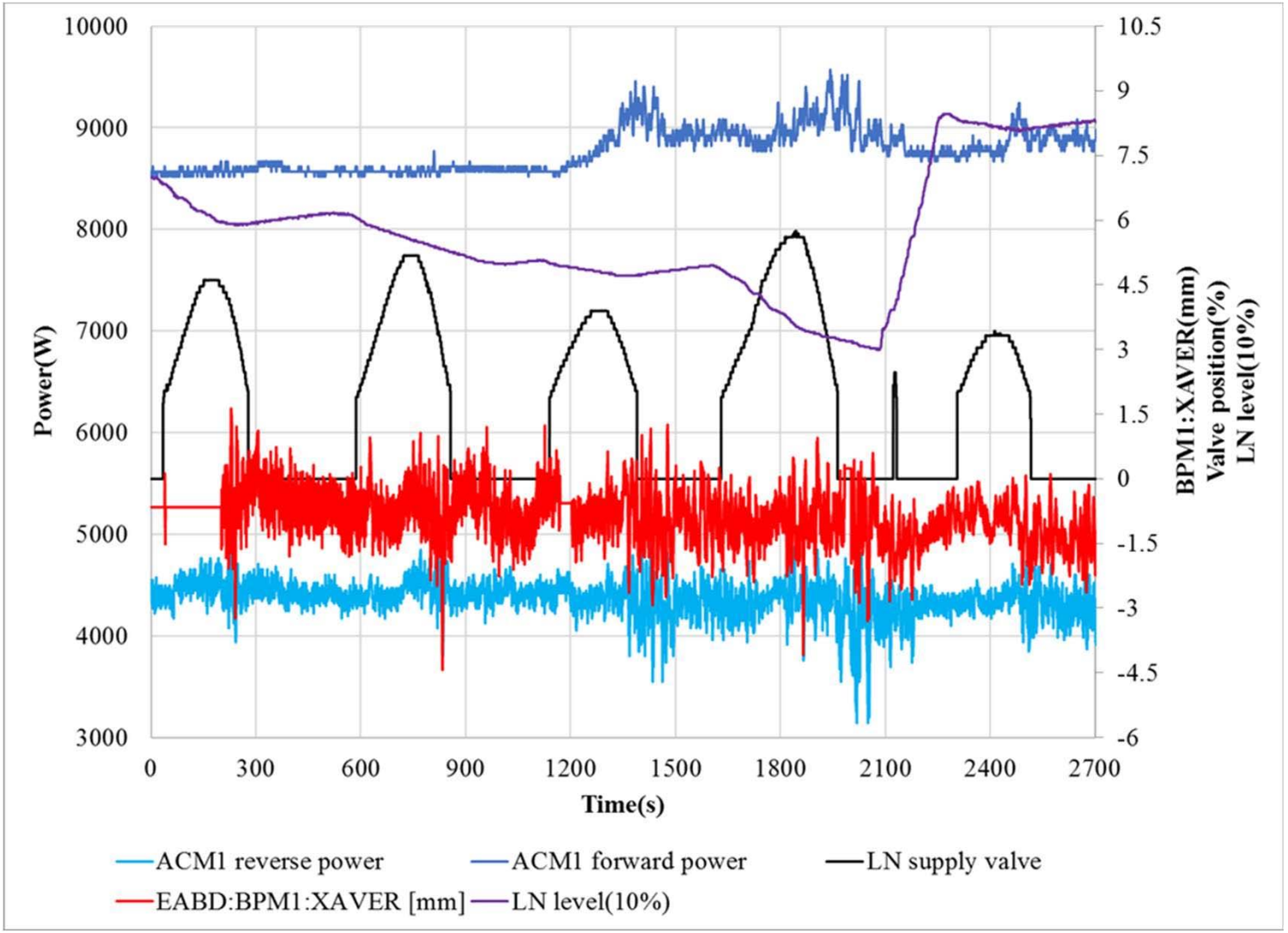
The LN level is not regulated. During refilling, there is lot of gas.

Disturbance caused by LN system

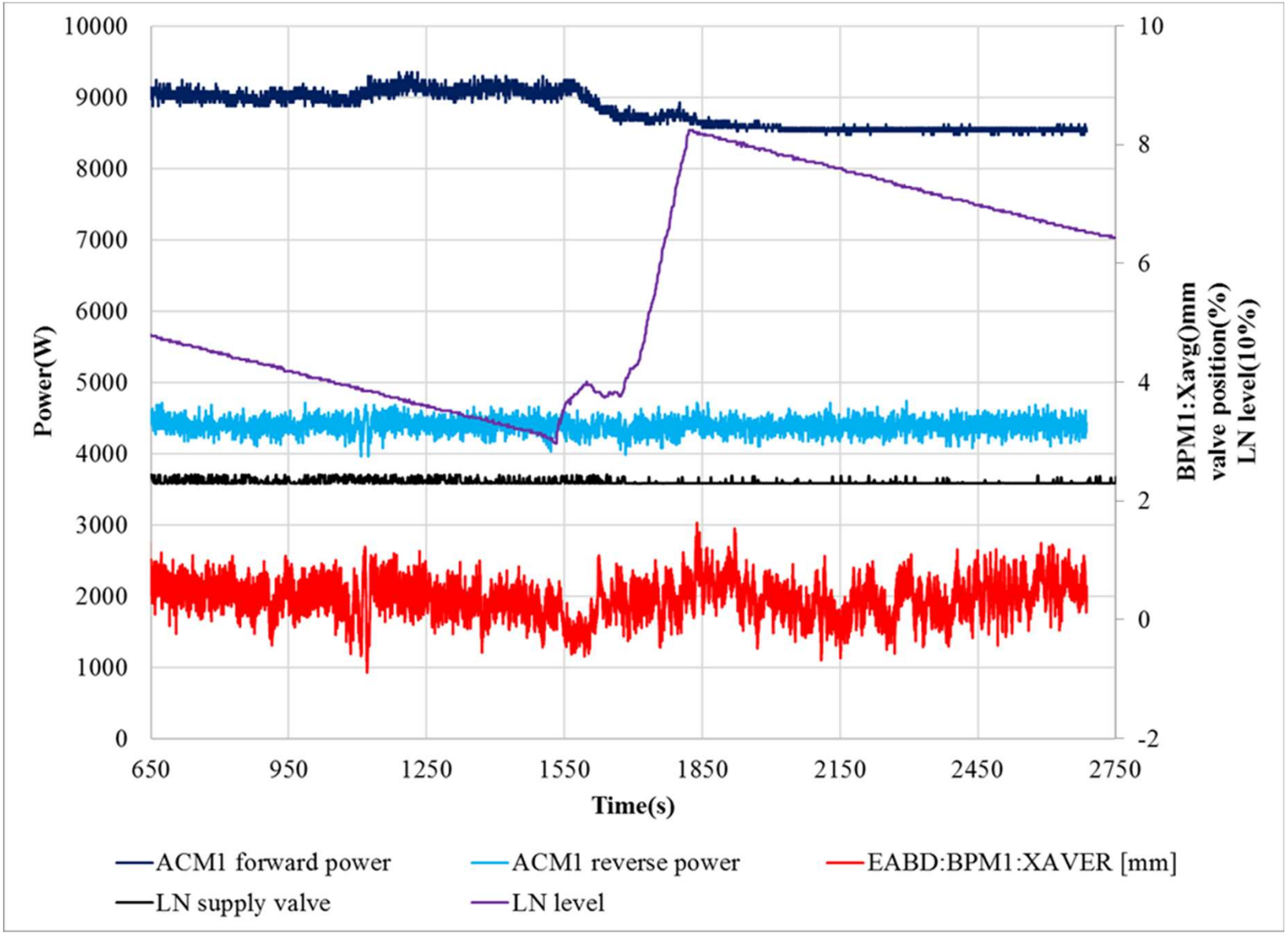


- The RF power fluctuation with LN_2 supply valve.
  - Initial regulated temperature was 130K
  - Reverse power showed 2 kW fluctuation
- Changed Regulated temperature to 120 K
  - the RF power fluctuation has been reduced

LN system disturbance during beam test



- Beam energy had disturbance which correlated with LN valve status.
- 1mm beam fluctuating ~0.12% of energy fluctuating



- Change LN supply valve to constant opening mode. The overall beam energy stability is about ±0.1% with 22 MeV (14MV energy gain from ACM1) final energy.
- The LN refilling process still affects beam energy and RF power.

LN2 system improvement proposal

- Phase Separator:
  - Phase separator is filled by a solenoid valve that opens when the level reaches 30% and closes at 80%.
  - To change the solenoid valve to a flow proportional valve and regulate the level
- ACM1 LN2 Supply Valve:
  - The supply valve only opens a very small amount
    - Small band of operations makes it difficult to regulate the temperature.
  - Modify this valve
    - Give a larger band of operation and precise control.
- Test and compare different regulating PVs
  - The couplers temperature PVs

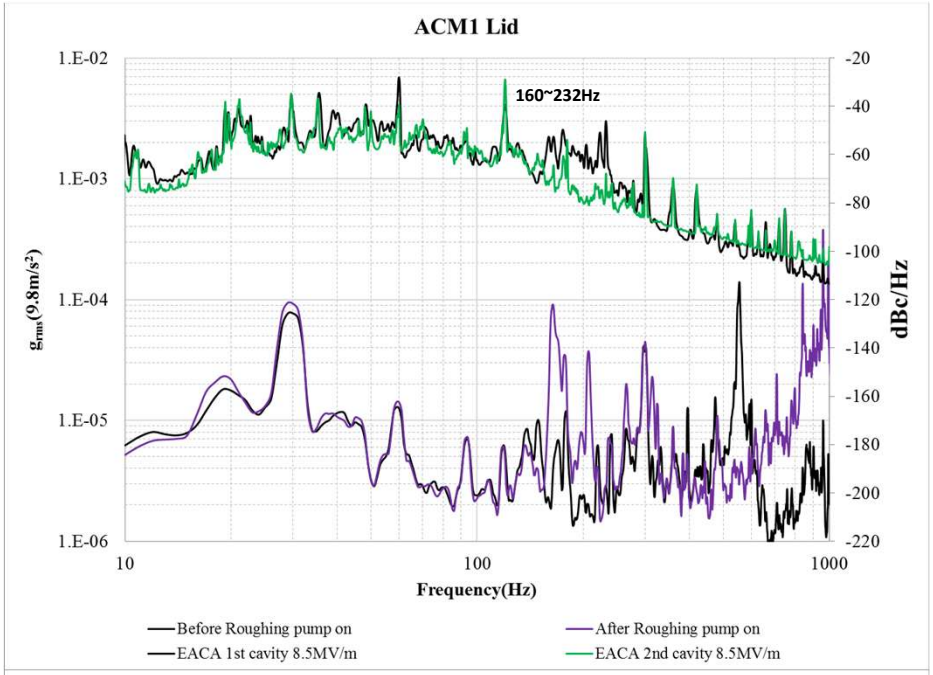
4. Microphonics source searching

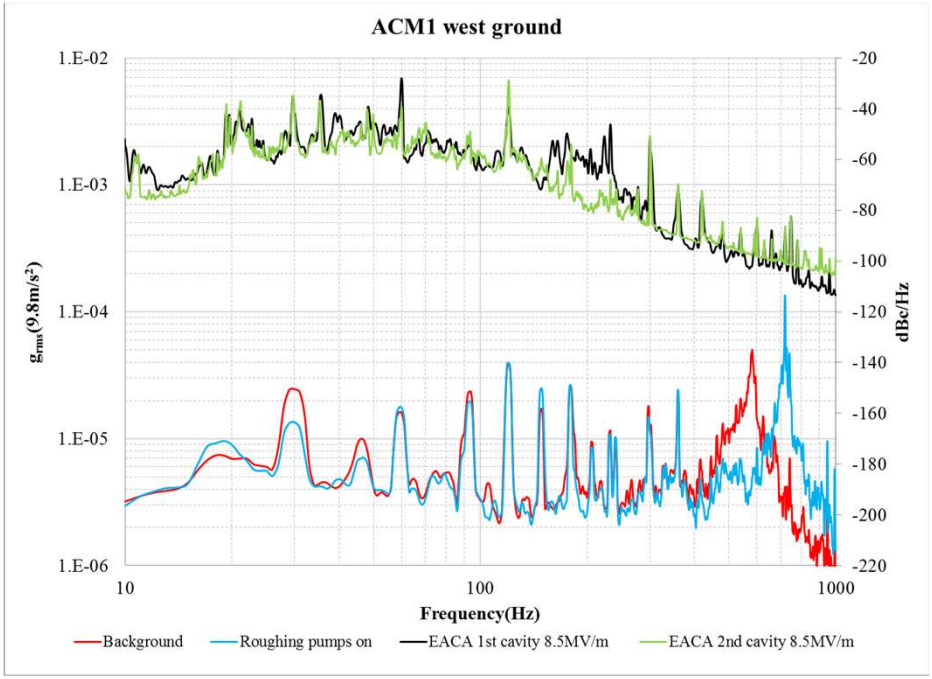
Sensors position

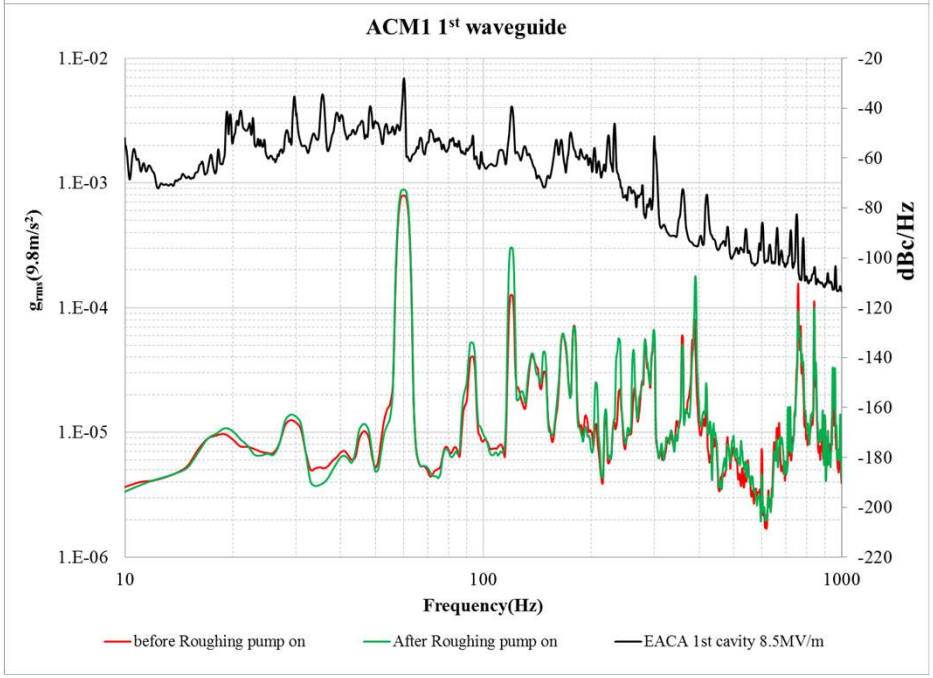
Turned on each noise source step by step

- Background----all pumps off
- turn on vacuum roughing pump
- Turbo pumps on
- B3 level pumps recovered
  - Provide waveguide parts cooling and Turbo pump cooling
- Both Klystron pumps on
- Couplers air cooling on
- Equipment used:
  - Accelerometer Dytran 3100D24T
  - Agilent 35670A

Roughing pump

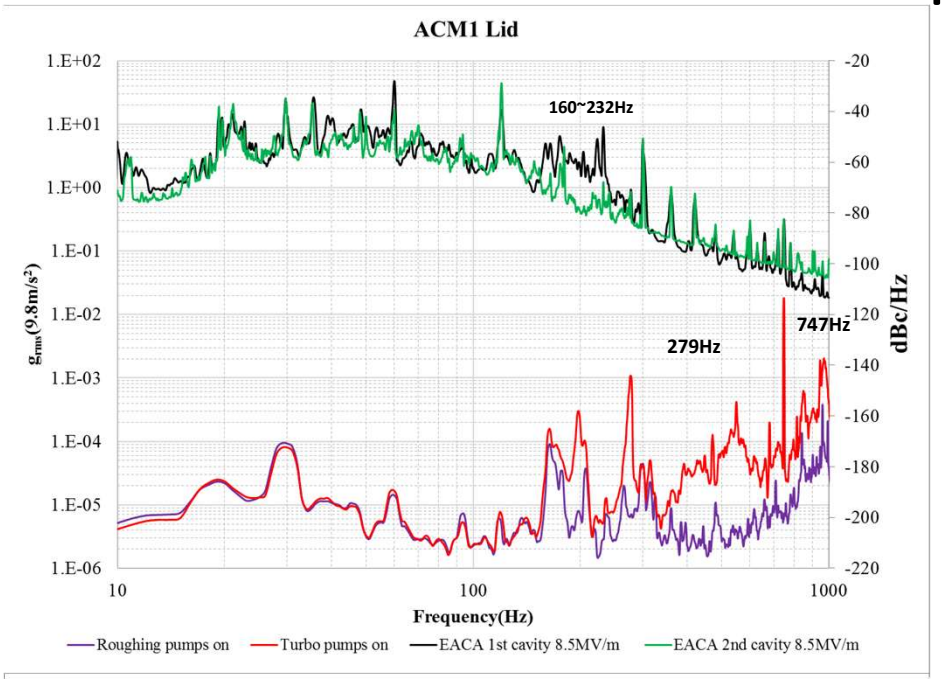


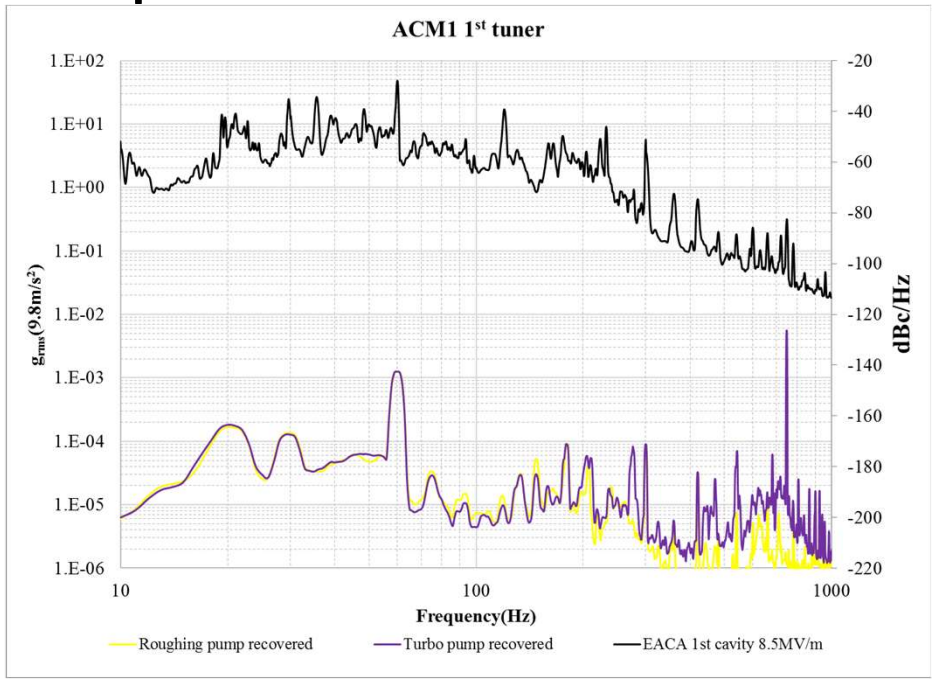


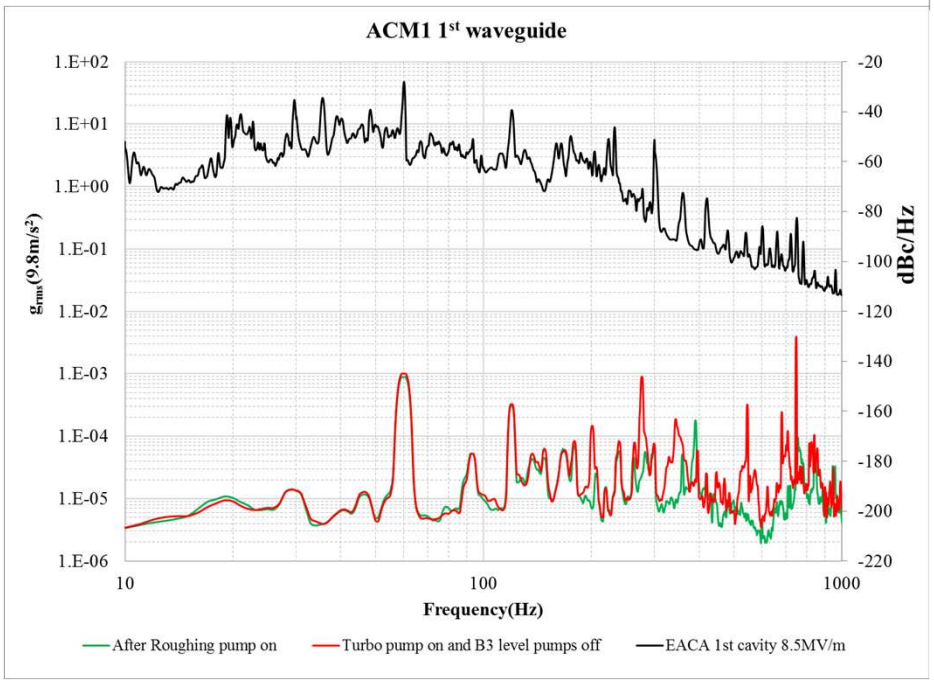


- During beam test
  - The roughing pumping bellow has been fixed;
  - The damping pad has been insert under roughing pump;
- The lid results show the pumping bellow need more damping;

Turbo pump on

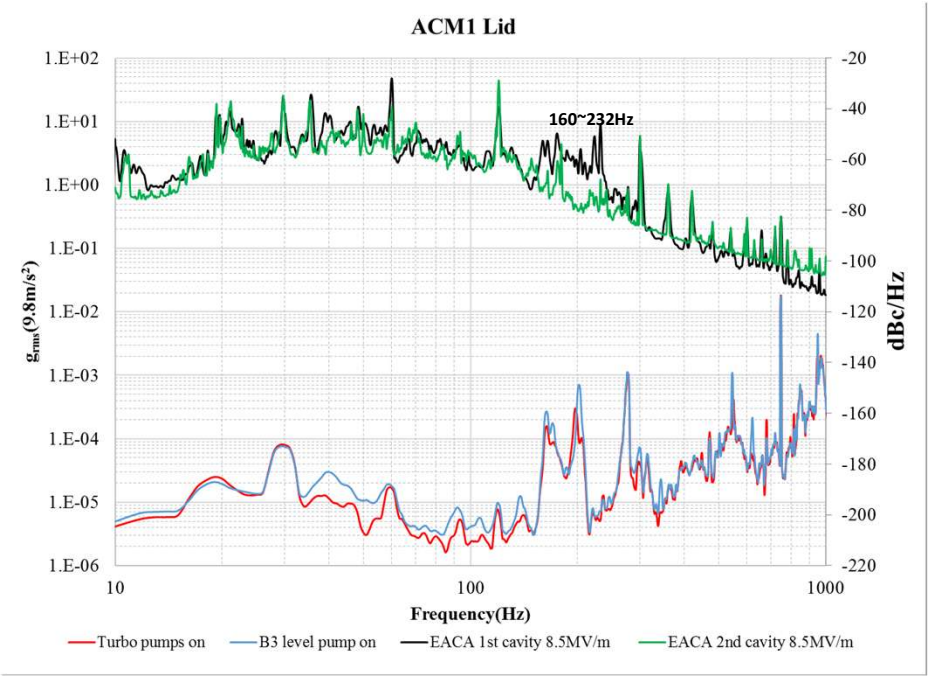


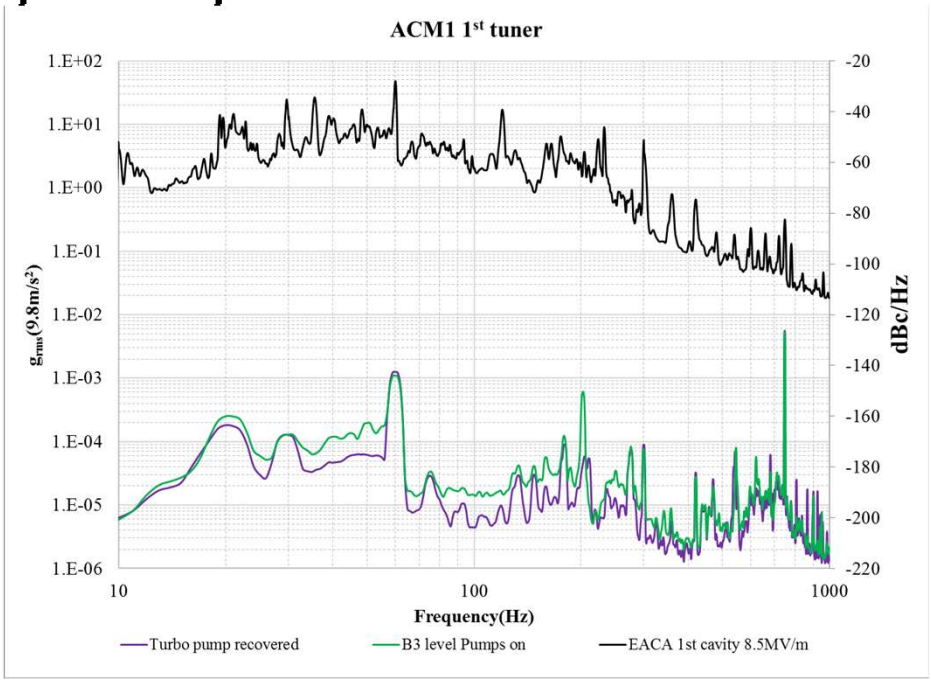


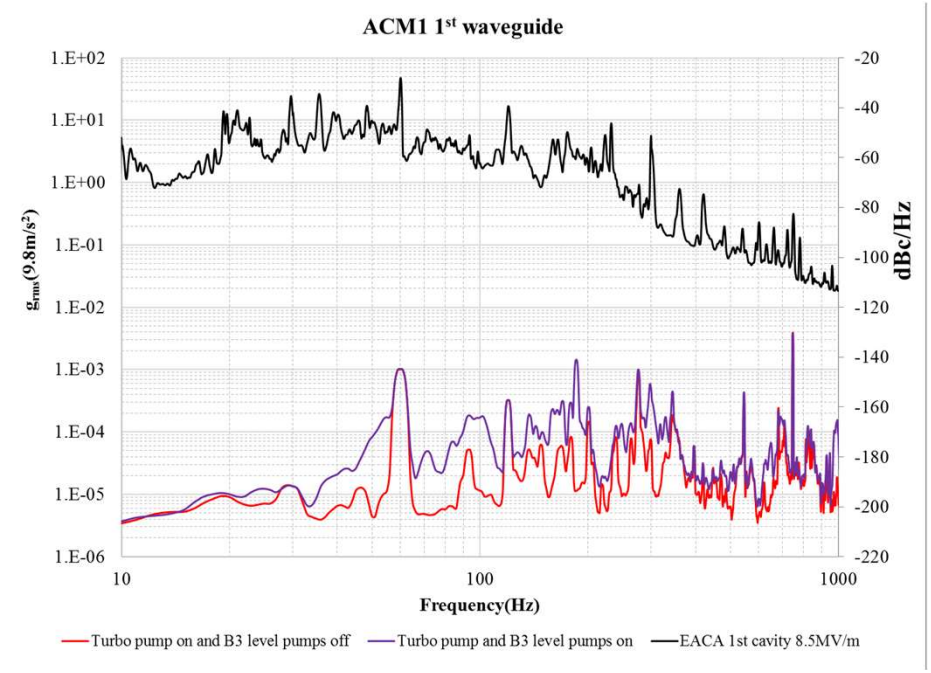


- Two turbo pumps are mounted on the top of cryomodule;
- The turbo pumps contributes noise on lid at higher than 160Hz range;

“B3 level” pump on

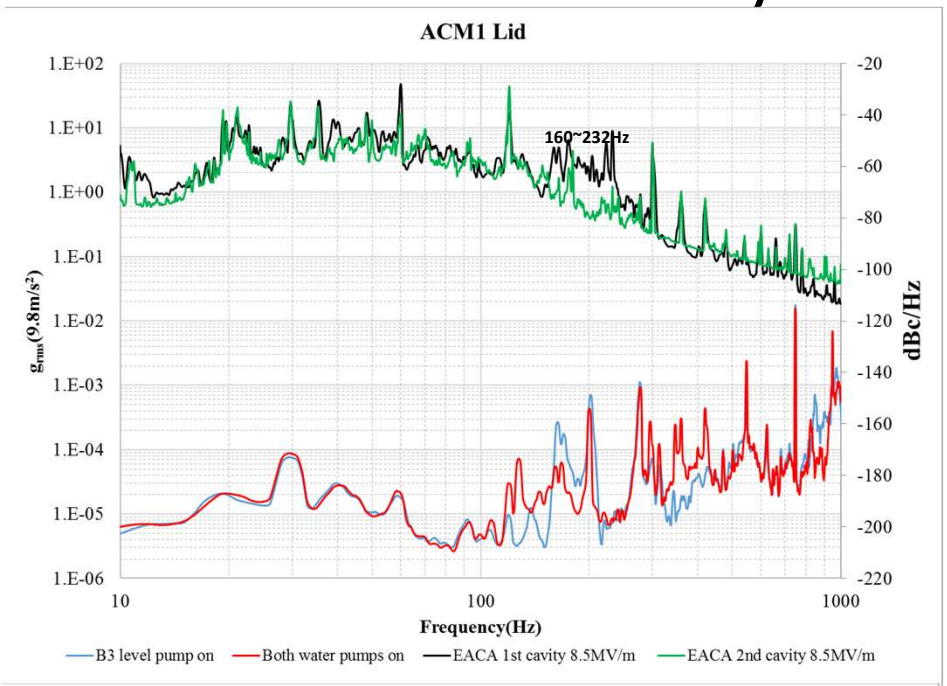


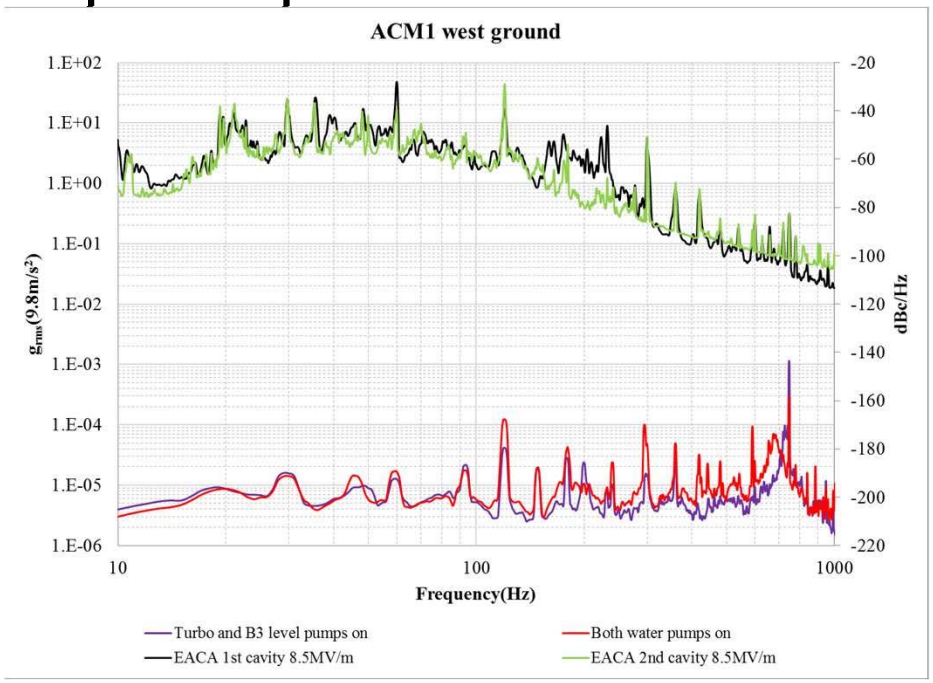


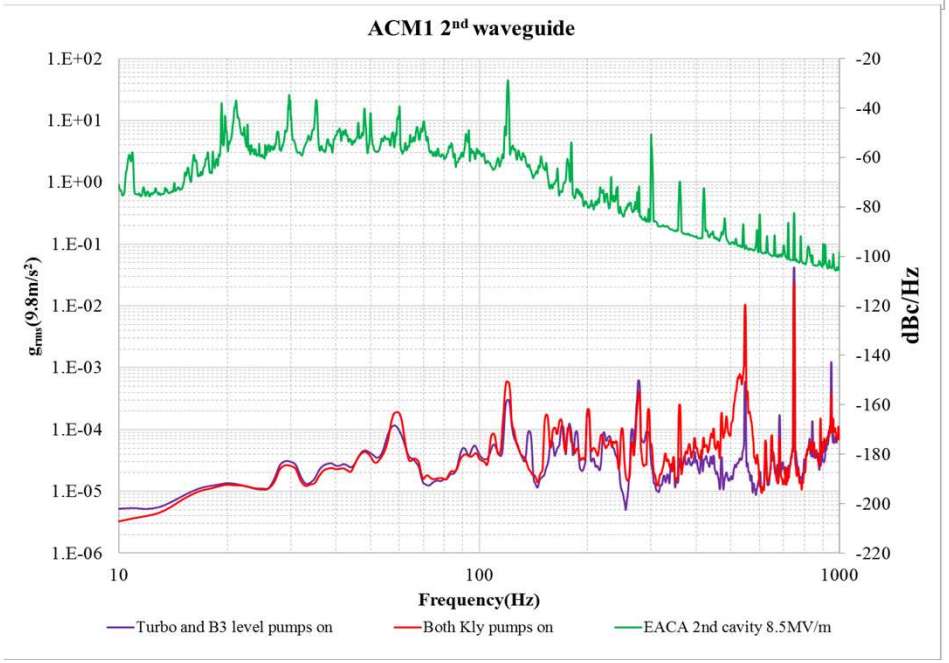


- The “B3 level” pumps provide waveguide parts cooling(including 50ohm loads, waveguide, power divide and couplers) and turbo pump cooling;
- It generates vibration through turbulence
- It increases the noise at lower than 300Hz, especially lower than 180Hz;

Both Klystron pumps on

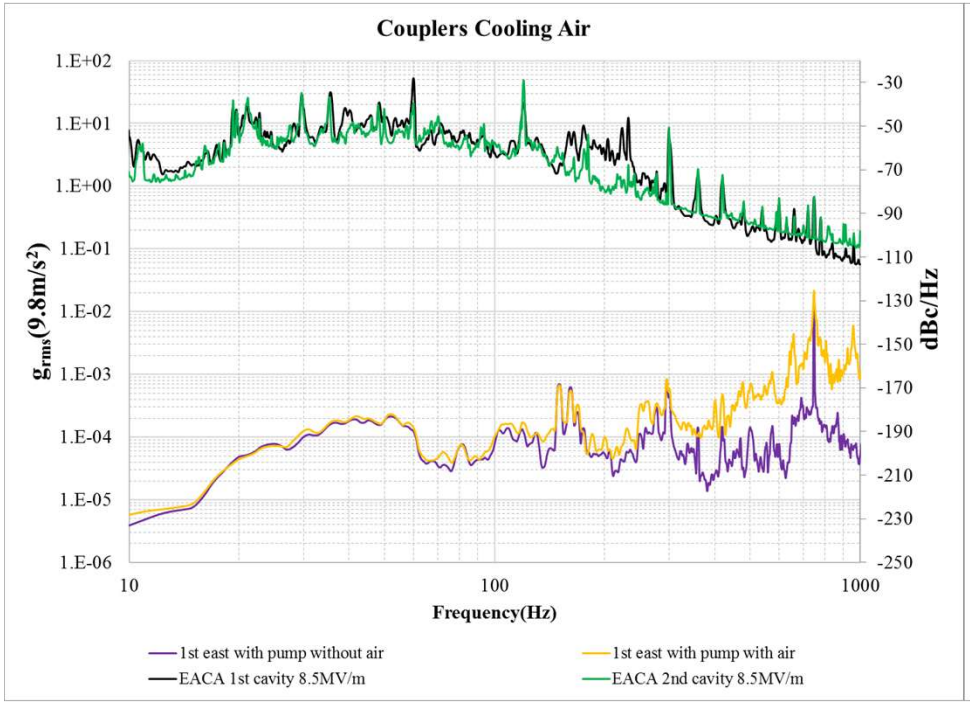


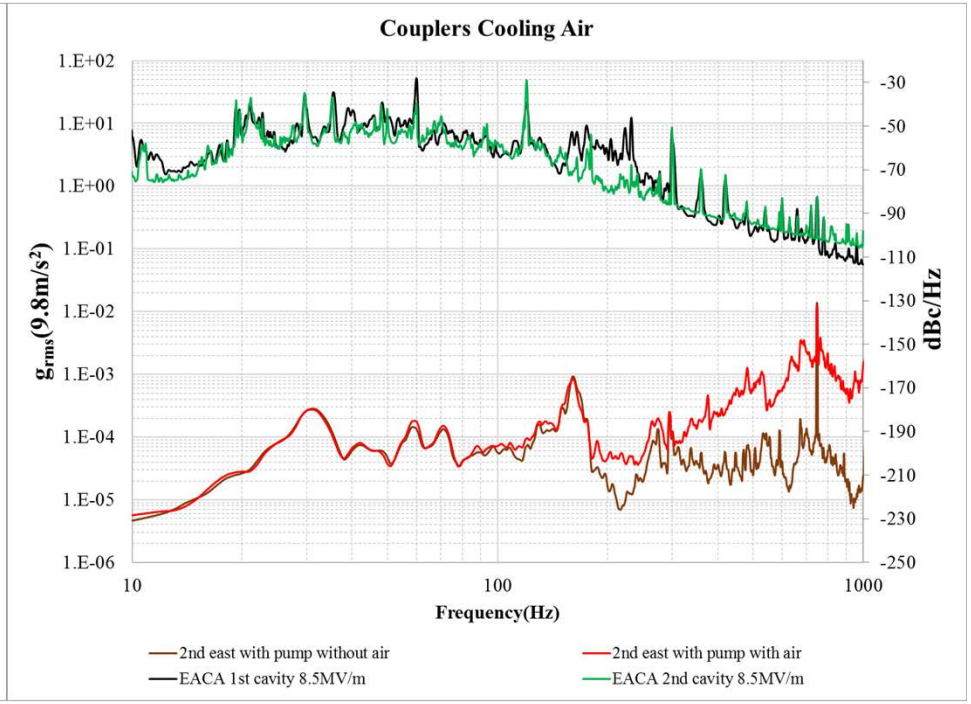




vibration becomes stronger with water pumps on

The coupler cooling air



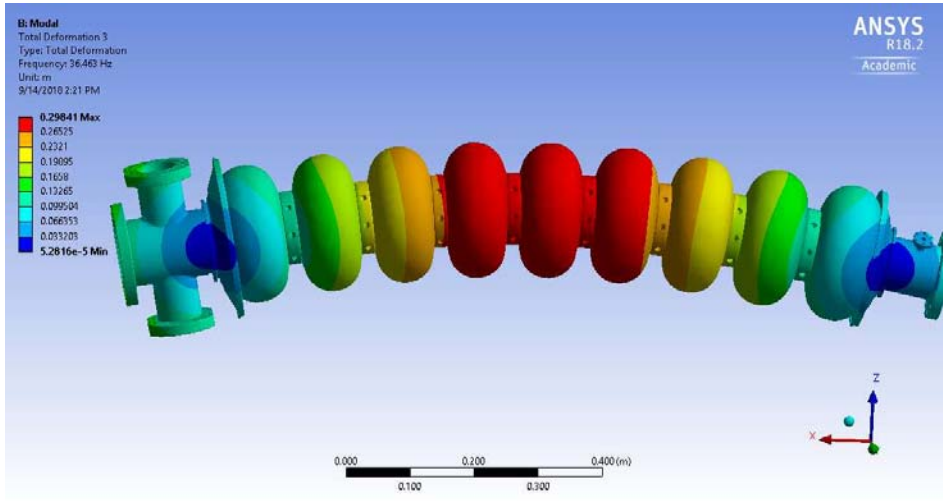


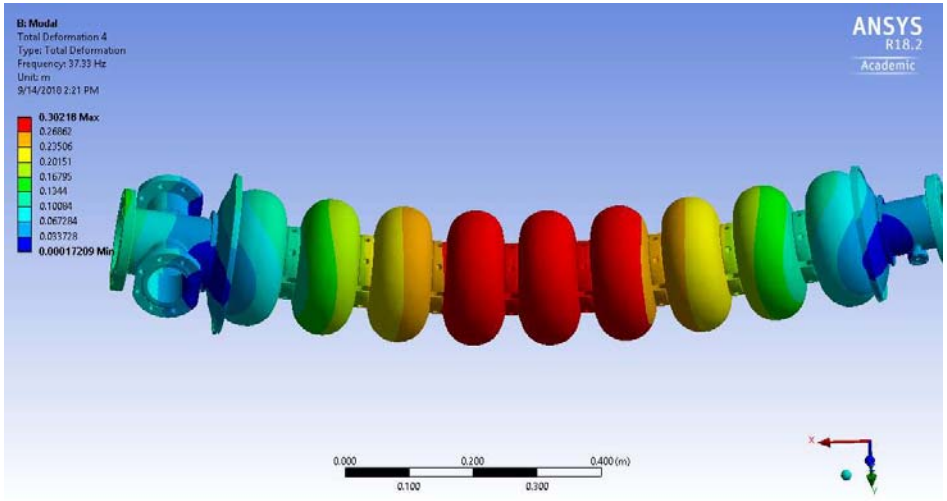
For the 1st east coupler, the coupler cooling air flow will increase noise at higher than 180Hz range

For 2nd east coupler ,the coupler cooling air flow will increase 60 and 72Hz peak.
It increases noise at higher than 180Hz range

The B3 level pump and vacuum system are normal

35Hz noise





The 35 Hz is a mechanical mode of cavity. The external vibration source has not been identified.

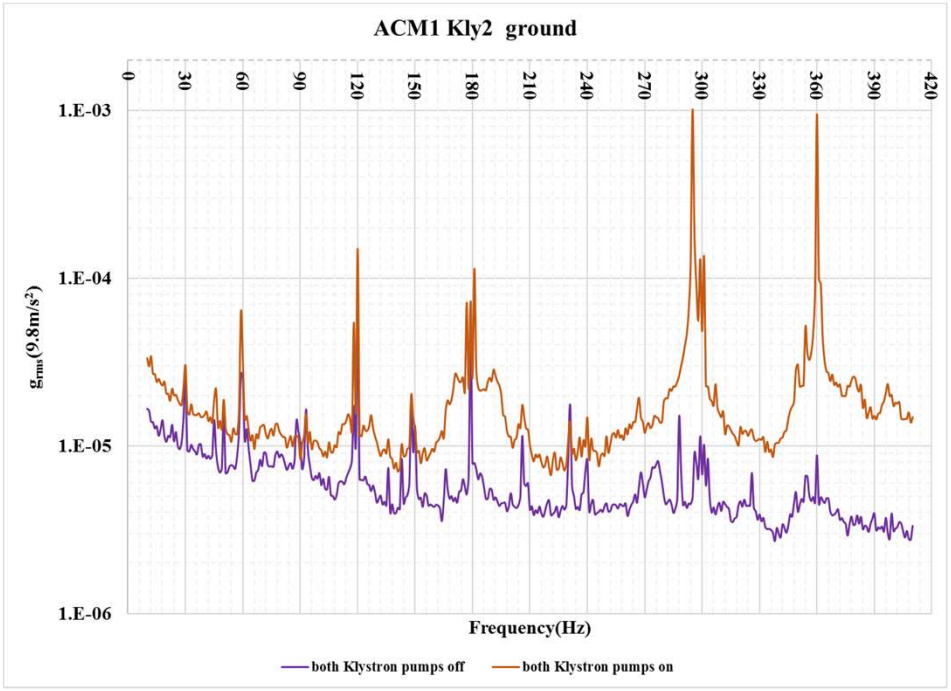
It shows correlation with couplers cooling air flow rate and the cooling fans status which was attached on the coupler warm section of the outer conductor.

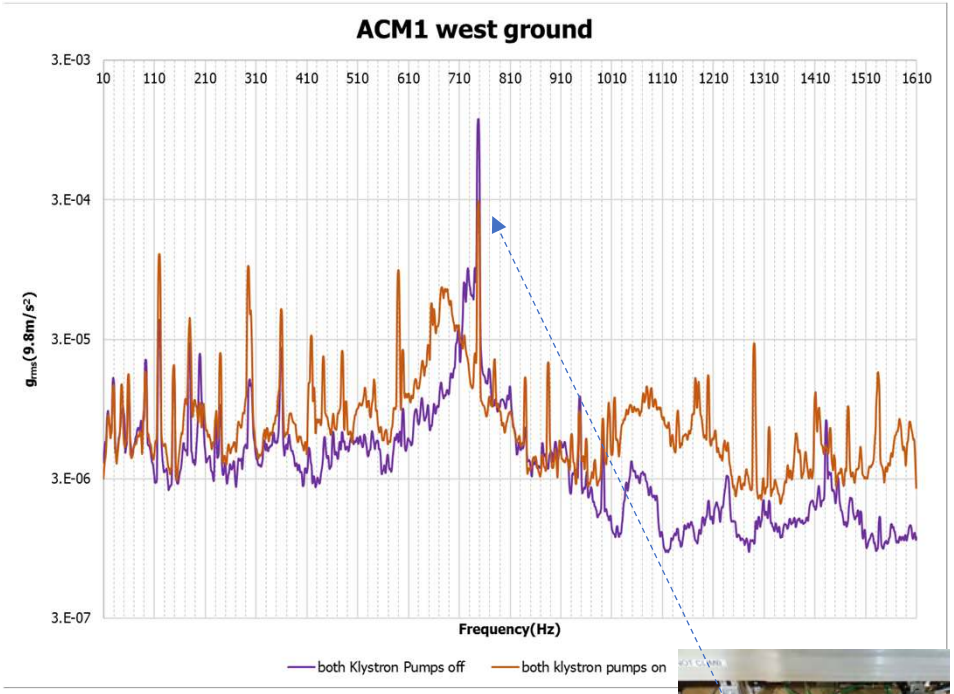
5. Water system investigation

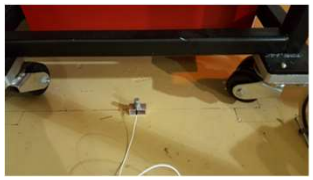
Water system

- Klystrons cooling water system consists two pumps;
- Klystron cooling water hoses are short;
- Rubber hoses of dummy loads are touched wave guide frame;
- Kly1 water supply pipe is supported by waveguide frame ;

Ground vibration related with water system

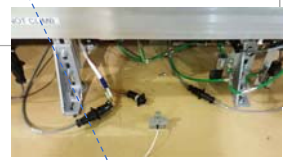






ACM1 Klystron ground

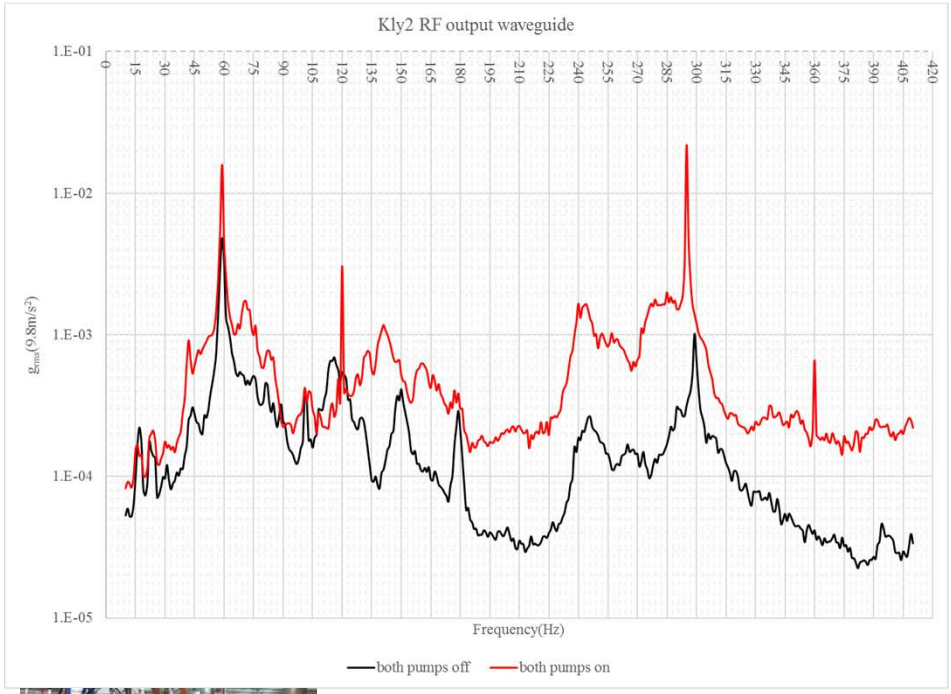
ACM1 west ground

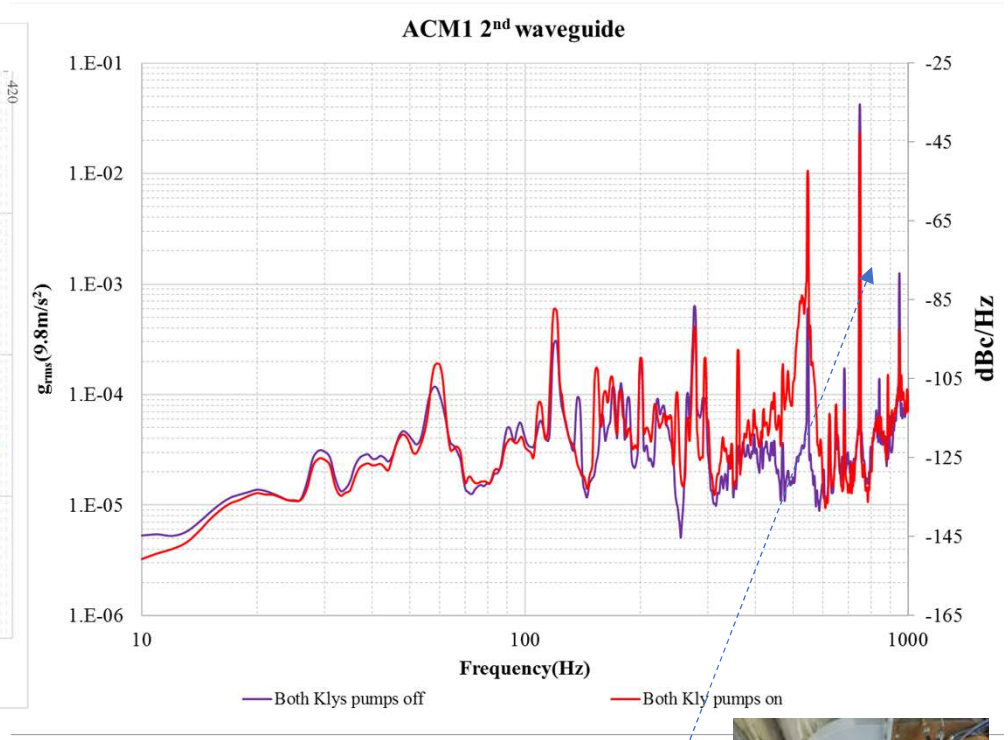


746Hz Turbo pump peak

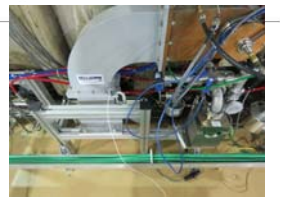
- The ground vibration becomes stronger with water pumps on

Waveguide Vibration



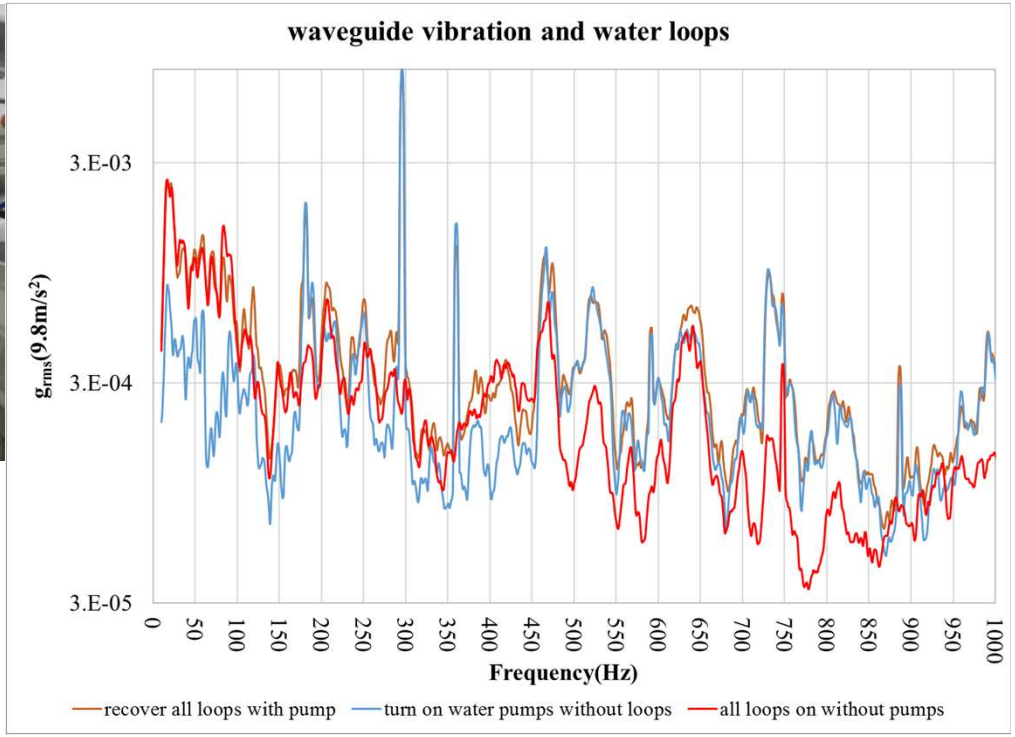


- The waveguide vibration becomes stronger with water pumps on



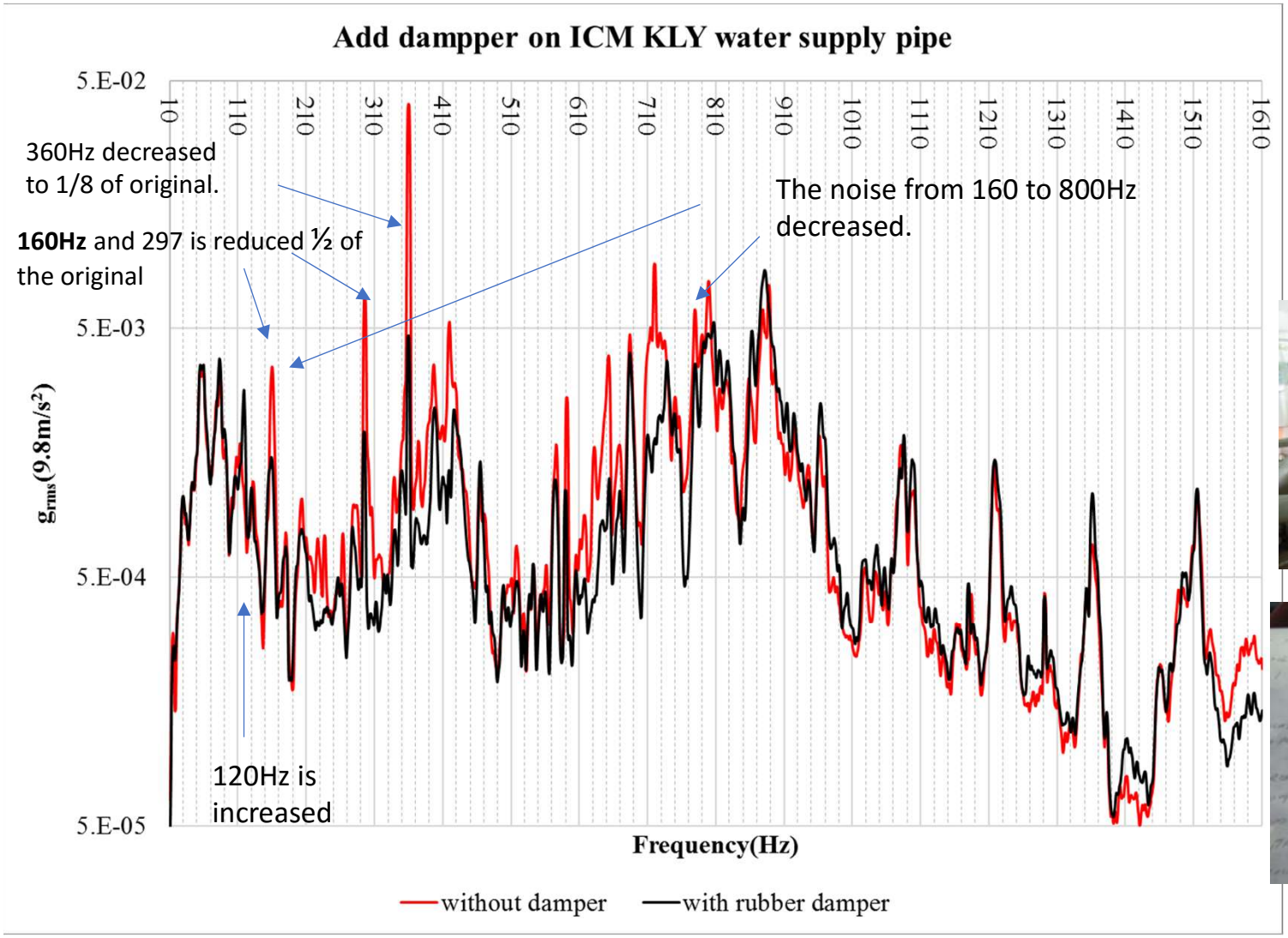
746Hz Turbo pump peak

Waveguide Vibration



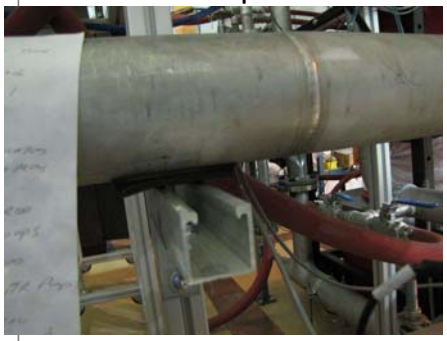
- Six 50 ohm loads are cooled by “B3 level” pump
- “B3 level” pump contribute <180Hz and ~410Hz noise
- the water pumps contribute the noise higher than 180Hz (except 410Hz) and the peaks valve higher as well.

These peaks by water pumps: 180,297,360Hz



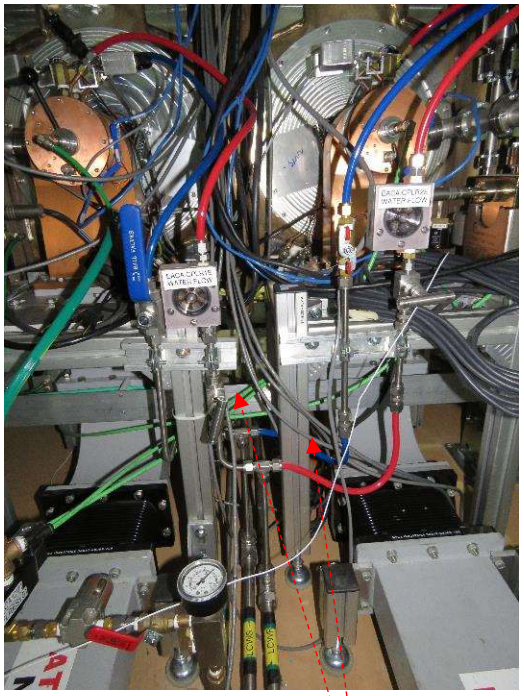
Sensor

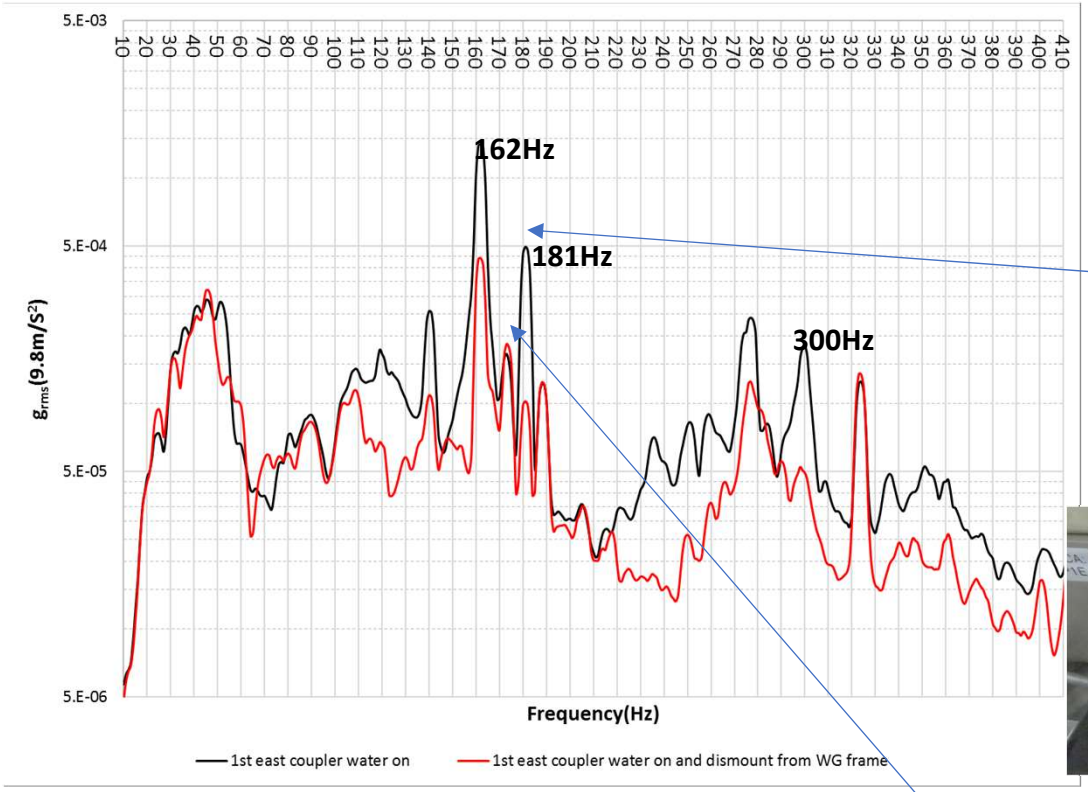
1st damper



2nd damper

The water cooling loops for ACM1 couplers





160Hz
After dismounted, the amplitude reduced to 1/3 of original.

Remaining related with waveguide and roughing pump

- Mounted to WG frame directly;
- The plastic pipes are short;
- 1st east coupler have metal pipes to supply pipe;
- After dismounted from WG frame, the vibration reduced.
- Based former background measurement the roughing pump bellows also contribute 160Hz noise

6. Discussion

- The Pondermotive effect showed when the total gradient about 17~18MV;
- The stability ACM1 cryomodule has been improved during beam test;
  - Several damping method have been implanted
  - LN system disturbance has been studied
  - the ±0.1% energy stability has been achieved with 22MeV beam
    - ACM1 about 14MV contribution
- The water system, vacuum system and coupler cooling air are the Microphonics source
  - Water system and waveguide system damping is under way
  - To optimize the coupler cooling air flow rate and monitor the warm window temperature, infrared temperature sensors will be added to couplers
  - The vacuum system will be further damped
  - LN system upgrade is under way
- The effect of the LFD driving ponderomotive instabilities needs further investigation
  - Push the gradient limit beyond 20MV;
  - Improve the beam energy instability in the range of ±0.1%;

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Merci

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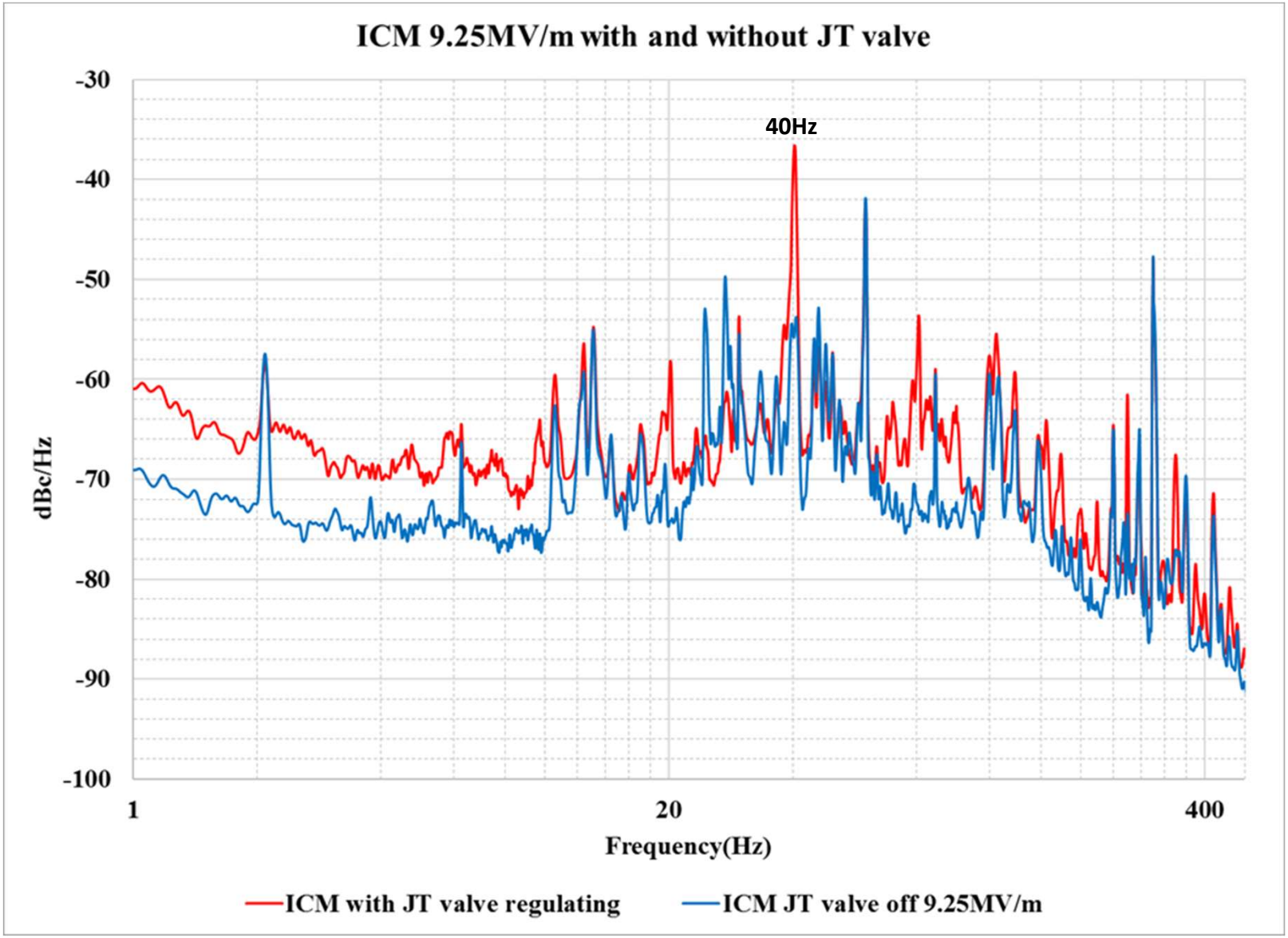
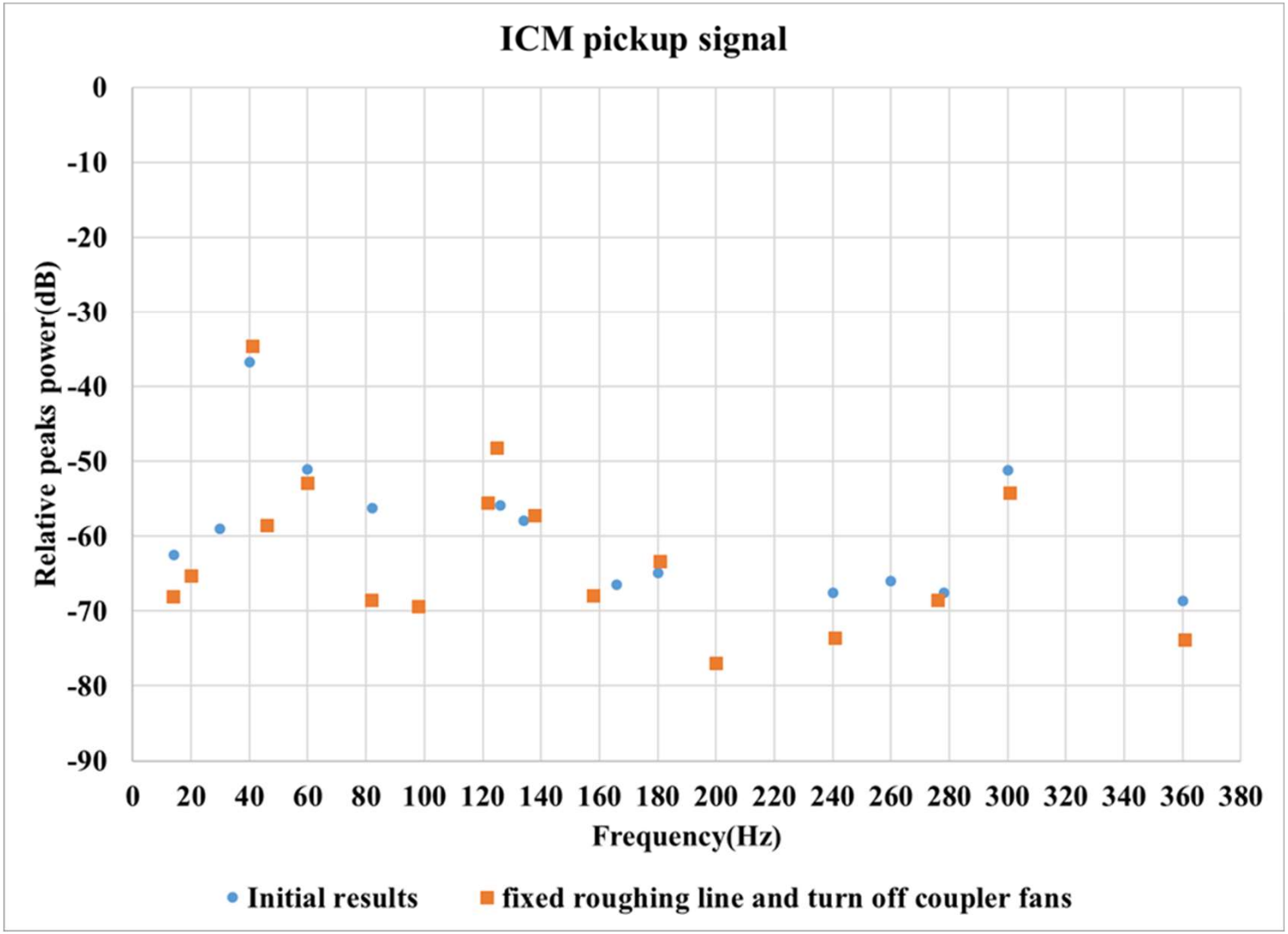
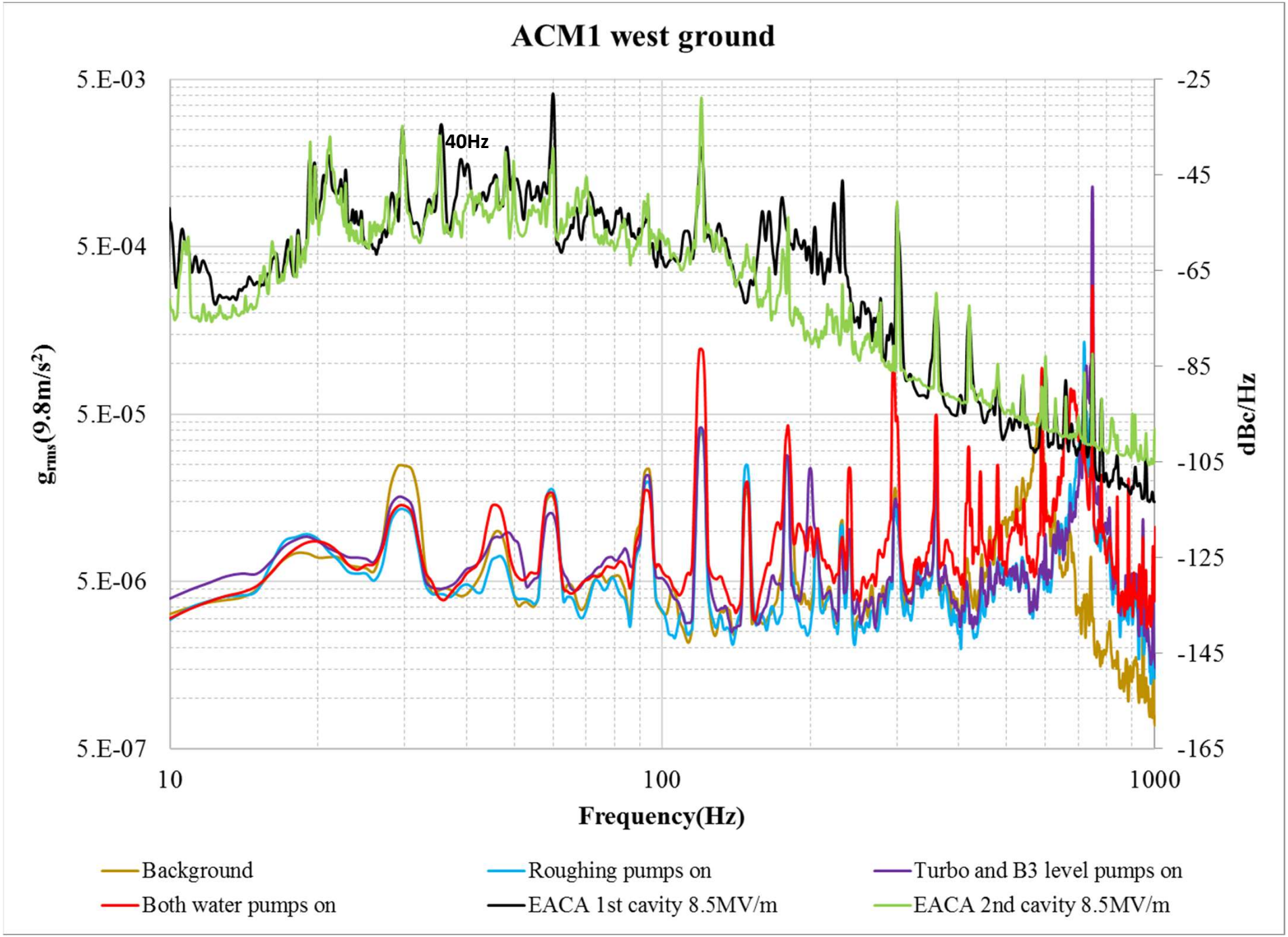


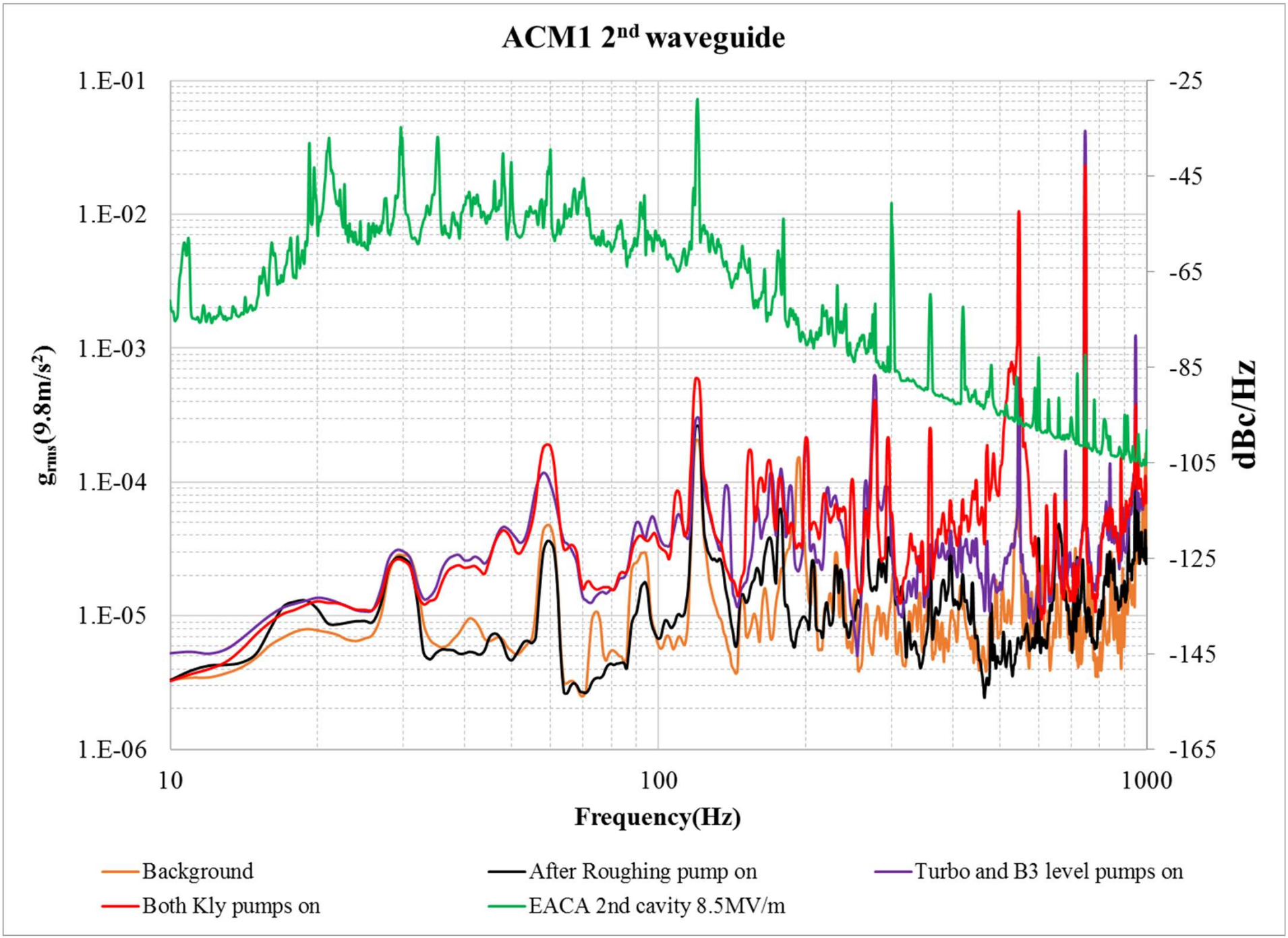
- Cryogenic test result reveals the ICM 40Hz noise is related with JT valve status.
- The 40Hz noise is also found in ACM1 1st cavity with less amplitude and disappear after JT valve closing.

ICM vibration damping



The ICM is working under SEL PLL mode. The similar vibration damping will be done.


ACM1 west ground
5.E-03
5.E-04
5.E-05
5.E-06
5.E-07
-25
-45
-65
-85
-105
-125
-145
-165
40Hz
10
100
1000
Frequency(Hz)
g_rms(9.8m/s²)
dBc/Hz
Background
Roughing pumps on
Turbo and B3 level pumps on
Both water pumps on
EACA 1st cavity 8.5MV/m
EACA 2nd cavity 8.5MV/m


ACM1 2nd waveguide
1.E-01
1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
grms(9.8m/s2)
-25
-45
-65
-85
-105
-125
-145
-165
dBc/Hz
10
100
1000
Frequency(Hz)
Background
After Roughing pump on
Turbo and B3 level pumps on
Both Kly pumps on
EACA 2nd cavity 8.5MV/m