BPM electrode and high power feedthrough -Special topics in wideband feedthrough-

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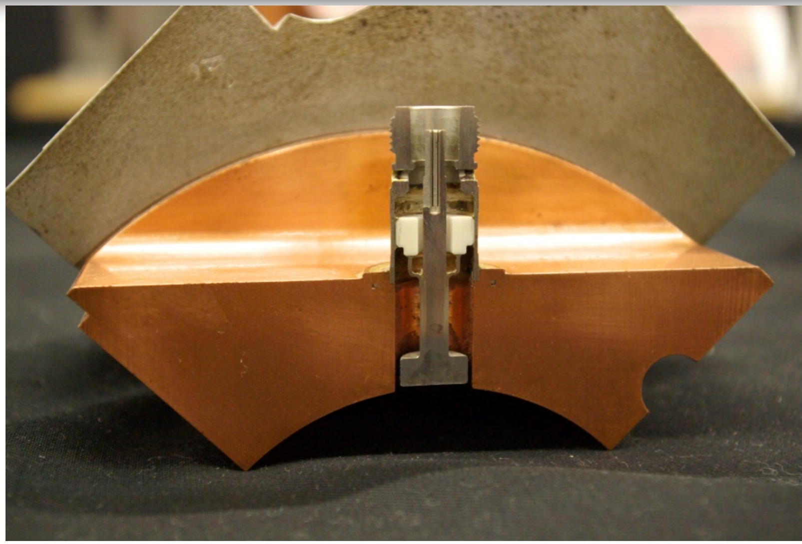
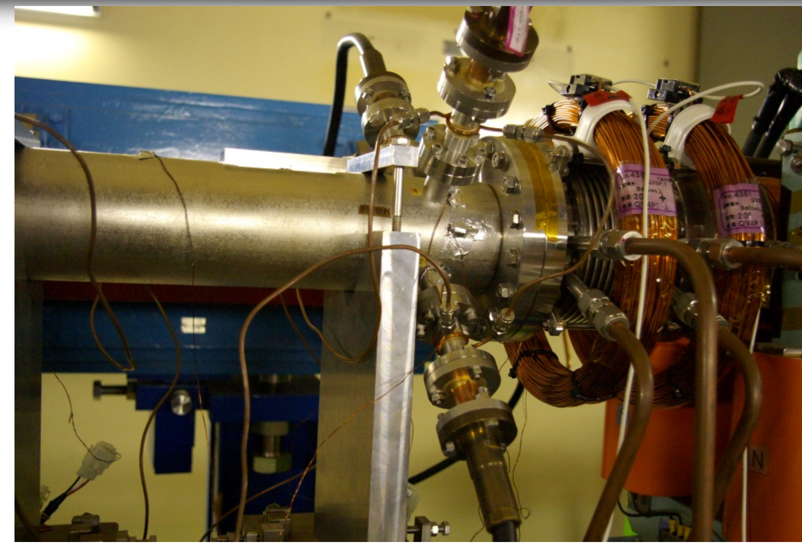
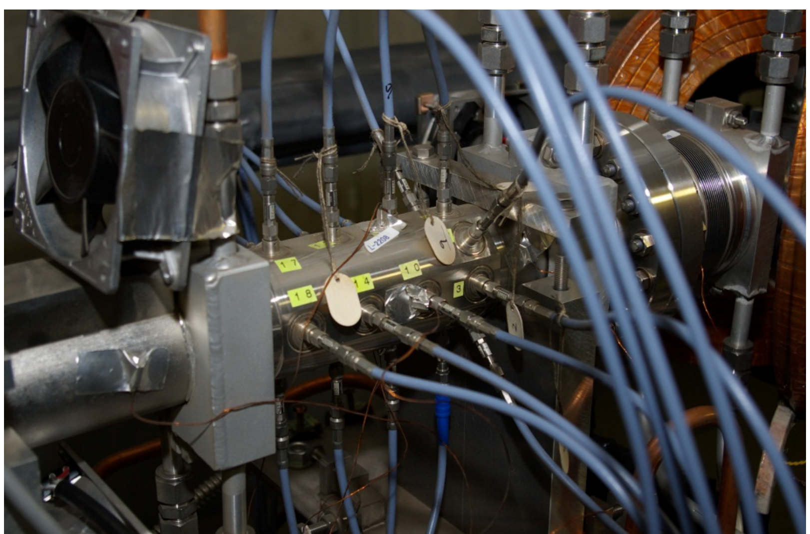
Introduction

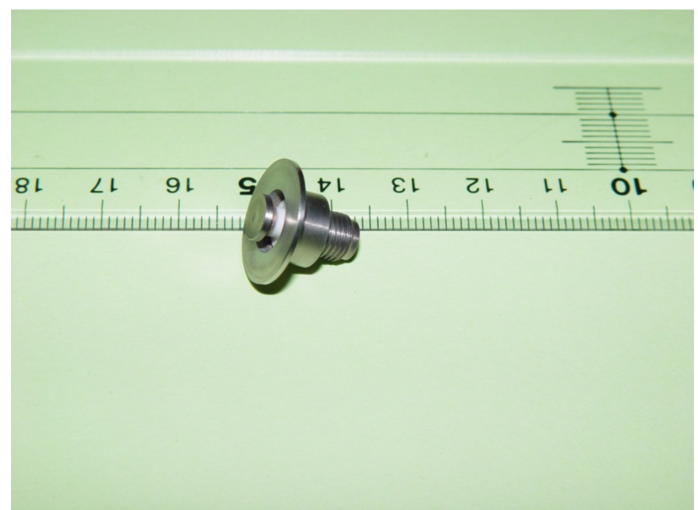
- **Beam runs in vacuum chambers (mostly) made of good-conducting metal.**
  - Vacuum chambers shield (fast) electro-magnetic wave from / to the beam.
  - Need some kind of "Feedthrough" to get / feed the electro-magnetic signal from / to beam.
- **Wideband coaxial feedthrough**
  - Button-type electrode
  - Stripline kicker / monitor
  - Plate-type position monitor
  - Ion (or electron cloud) clearing electrode

Feedthrough









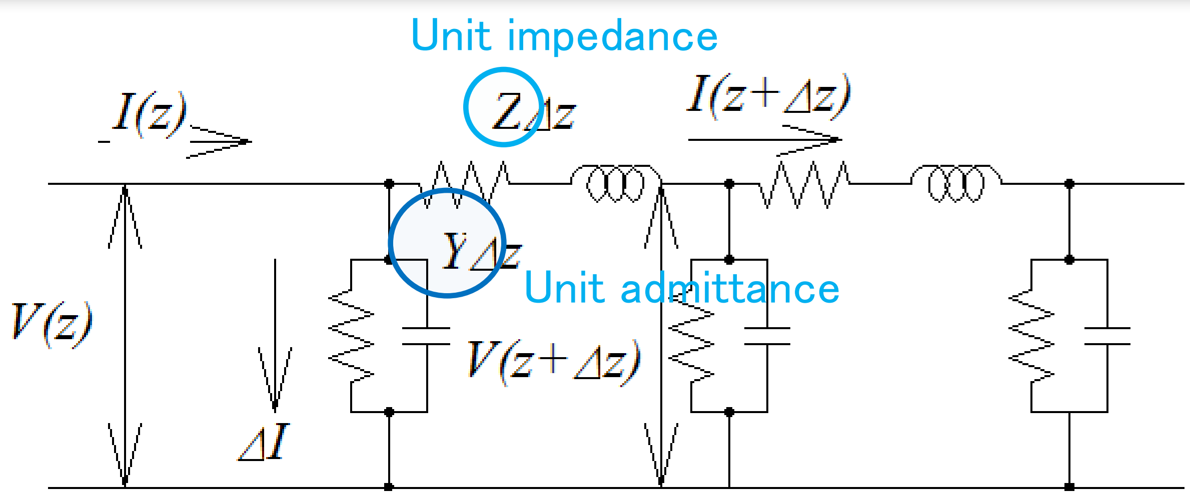
Need to consider..

- **Specification of the feedthrough**
  - Structure
    - Total size
    - Kind of RF connector, vacuum structure…
    - Mechanical (and heating) toughness
  - Frequency range, allowed SWR, reflection..
  - Power range
    - Beam induced power
    - Supplied power from outside
    - allowed (V)SWR

In this tutorial

- **Review of transmission line theory**
  - S-Parameter, (V)SWR
  - Time domain behavior (TDR)
- **Frequency-domain simulation**
  - Ansys HFSS
- **Time-domain simulation**
  - GdfidL
- **Design, evaluation of the button electrodes**
- **Design, evaluation of the high-power feedthroughs**
- **Summary**

Circuit representation of a uniform transmission line



$$\Delta V = -IZ\Delta z$$

$$\Delta I = -VY\Delta z$$

$$\frac{dV}{dz} = -IZ$$

$$\frac{dI}{dz} = -VY$$

$$\frac{d^2V}{dz^2} = \gamma^2 V, \frac{d^2 I}{dz^2} = \gamma^2 I$$

$$\gamma^2 = ZY$$

Transmission line (cont.)

- **Solution**

$$V = V_1 e^{-\gamma z} + V_2 e^{\gamma z}$$
$$= V_1 e^{(j\omega t - \gamma z)} + V_2 e^{(j\omega t + \gamma z)}$$

- **Normal transmission line**

Resistance Inductance

$$Z = R + jL\omega$$
$$Y = G + jC\omega$$

Parallel conductance Capacitance

$$\gamma = \left(LC\omega^2\right)^{\frac{1}{2}}\left[1 - \frac{RG}{LC\omega^2} - j\left(\frac{G}{C\omega} + \frac{R}{L\omega}\right)\right]^{\frac{1}{2}}$$
$$\approx j\omega\sqrt{LC}\left[1 - j\left(\frac{G}{C\omega} + \frac{R}{L\omega}\right)\right]^{\frac{1}{2}}$$
$$\approx j\omega\sqrt{LC}\left(1 - j\frac{R}{2L\omega}\right)$$

Propagation constant

$$\gamma = \alpha + j\beta$$

$$\alpha = \frac{R}{2}\sqrt{\frac{C}{L}}, \beta = \omega\sqrt{LC}$$

$$V = V_1 e^{j(\omega t - \beta z)} e^{-\alpha z} + V_2 e^{j(\omega t + \beta z)} e^{\alpha z}$$

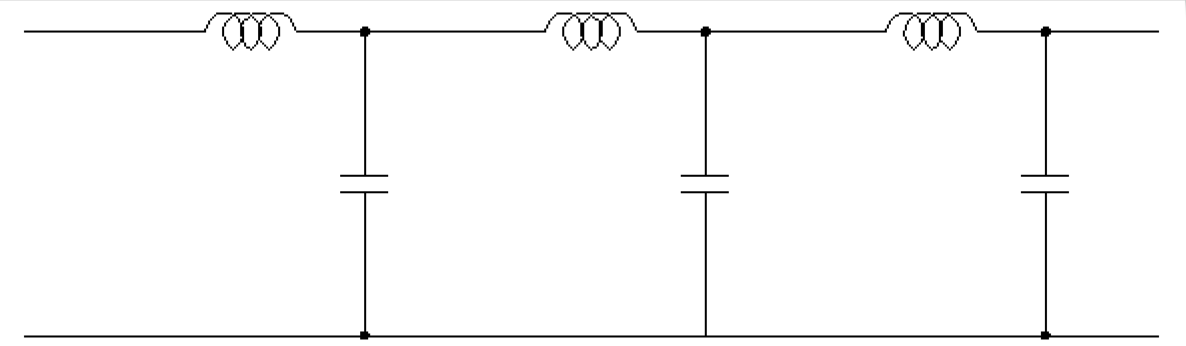
- **Phase velocity**

$$v_p = \frac{dz}{dt} = \frac{\omega}{\beta} = \frac{1}{\sqrt{LC}}$$

- **If phase velocity = group velocity**

$$\beta = \frac{2\pi f}{f\lambda} = \frac{2\pi}{\lambda}$$

Loss less line



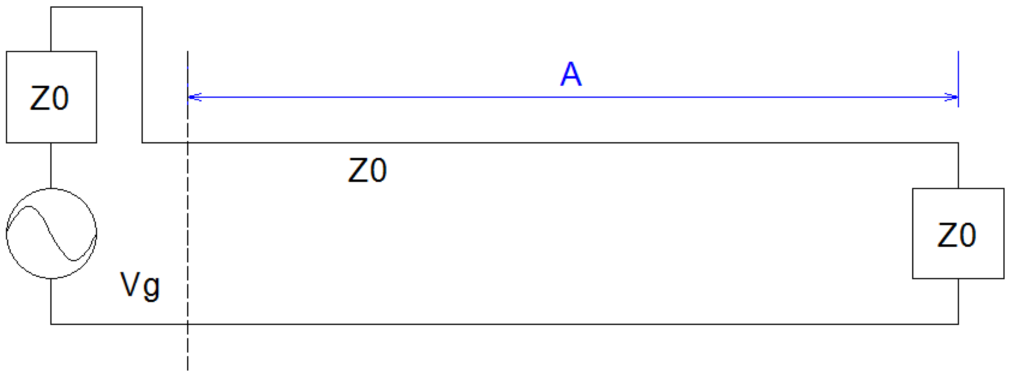
$$V = V_1 e^{-j\beta z} + V_2 e^{j\beta z}$$

$$I = \frac{1}{Z_0}\left(V_1 e^{-j\beta z} - V_2 e^{j\beta z}\right)$$

$$Z_0 = \frac{Z}{\gamma} = \sqrt{\frac{L}{C}}$$

$$\beta = \omega\sqrt{LC}$$

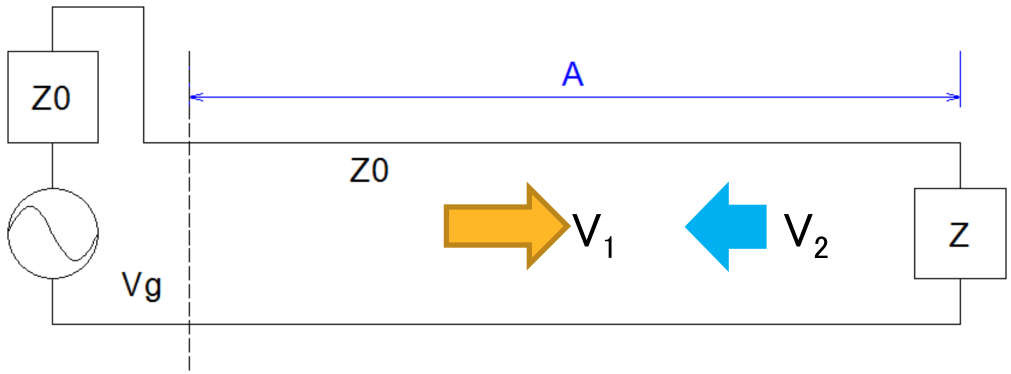
Impedance matched line



$$\frac{V(A)}{I(A)} = Z_0 = Z_0 \frac{V_1 e^{-j\beta A} + V_2 e^{j\beta A}}{V_1 e^{-j\beta A} - V_2 e^{j\beta A}} \qquad V_2 = 0$$

- **No reflection! (Only forwarding wave exist)**

Arbitrary termination

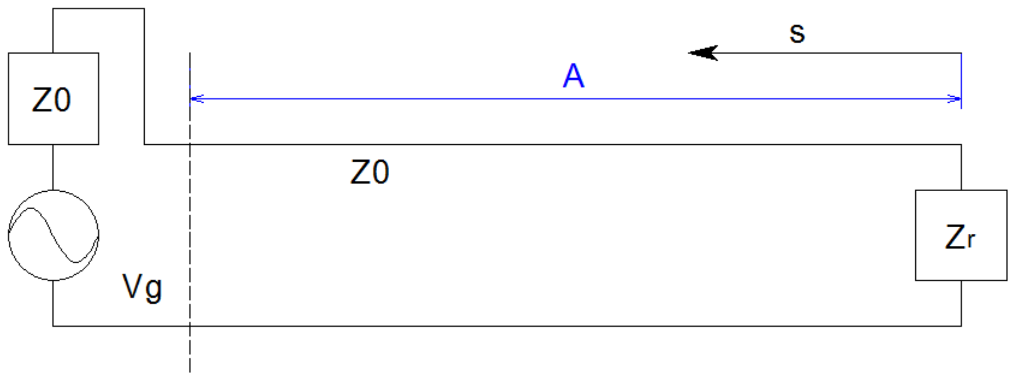


- To satisfy V(A)/I(A)=Z, we need both forwarding and reflecting wave.

$$V = V_1 e^{-j\beta z}\left(1+2\frac{|V_2|}{|V_1|}\cos\chi+\frac{|V_2|^2}{|V_1|^2}\right)^{\frac{1}{2}}\exp\left(j\tan^{-1}\frac{\frac{|V_2|}{|V_1|}\sin\chi}{1+\frac{|V_2|}{|V_1|}\cos\chi}\right)$$

$$\chi = 2\beta z+\theta_2-\theta_1$$

Standing wave



$$V = V_1 e^{-j\beta(A-s)} + V_2 e^{j\beta(A-s)} = V_1^{'} e^{j\beta s} + V_2^{'} e^{-j\beta s}$$

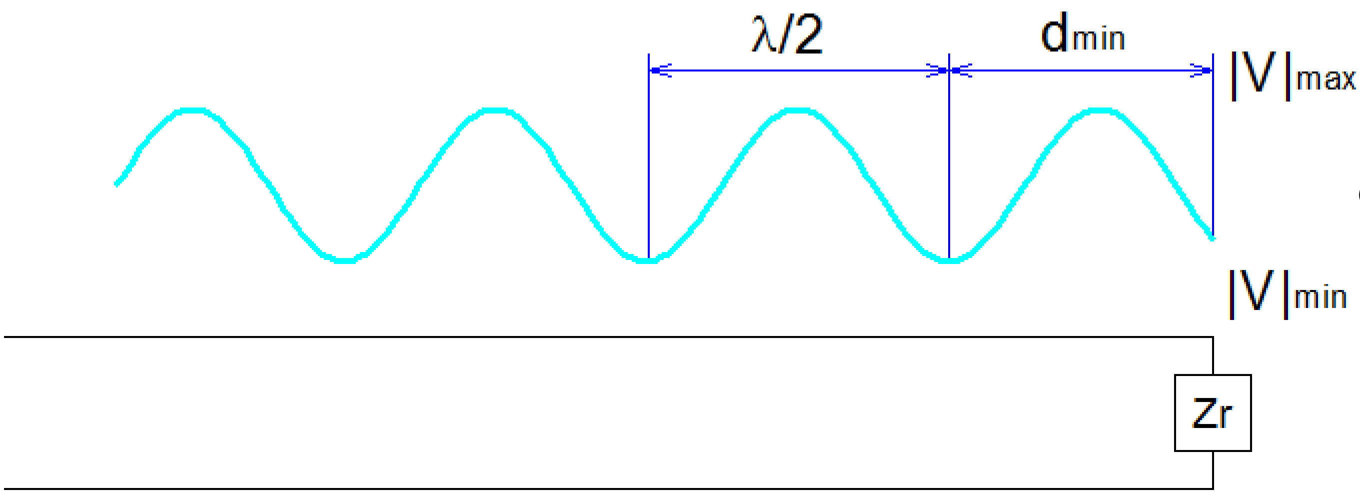
$$= V_1^{'} e^{j\beta s}\left(1 + \rho e^{-2j\beta s}\right)$$

- ρ: reflection constant

$$\rho = \frac{V_2^{'}}{V_1^{'}} = |\rho| e^{j\varphi}$$

$$V = V_1^{'} e^{j\beta s}\left(1 + |\rho| e^{j(\varphi - 2\beta s)}\right)$$

Standing wave ratio



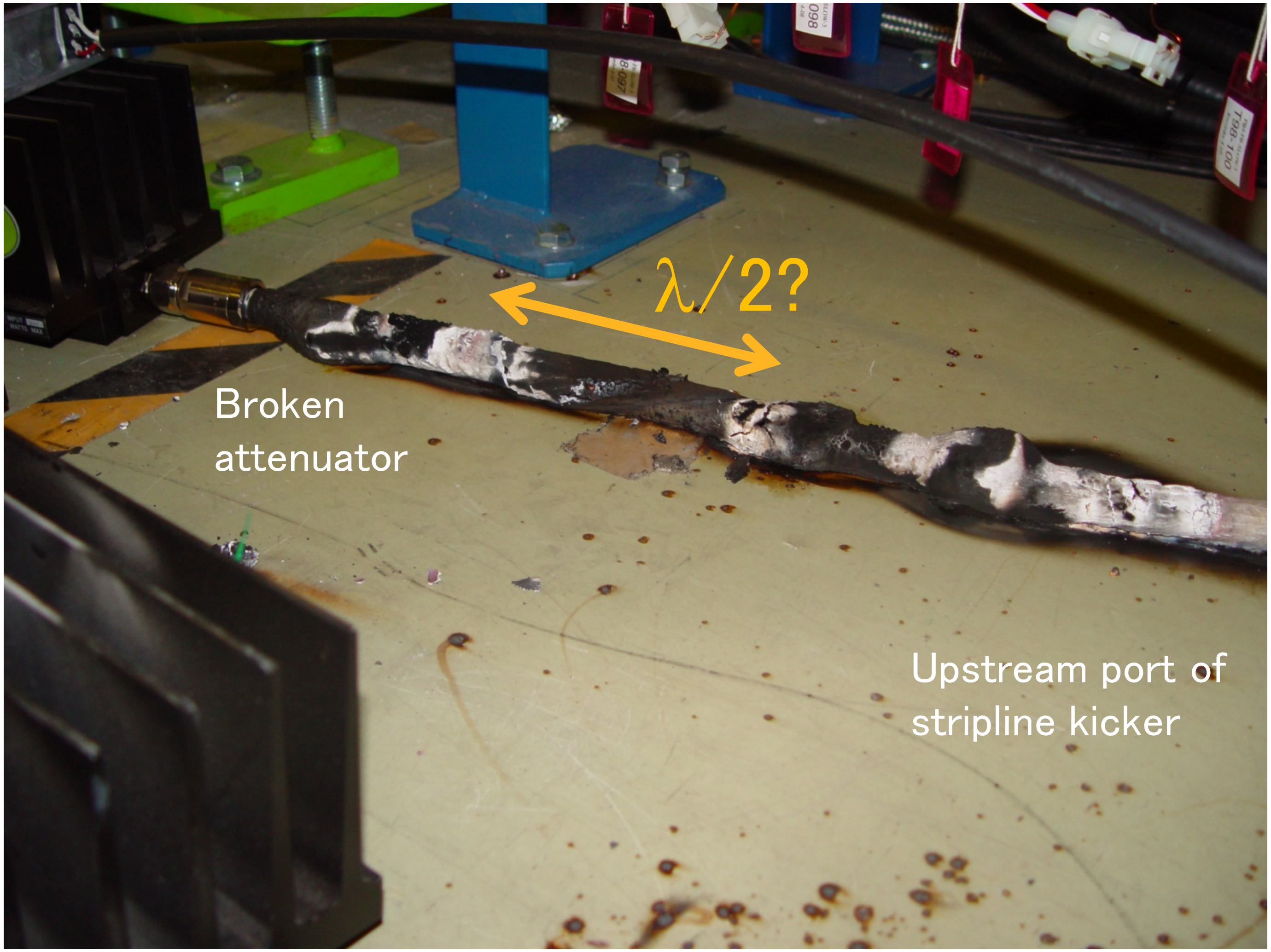
$$\varphi - 2\beta d_{\min} = \pi$$

- **Standing wave ratio (SWR)**

$$S = \frac{|V|_{\max}}{|V|_{\min}} = \frac{1+|\rho|}{1-|\rho|}$$

$$|\rho| = \frac{S-1}{S+1}$$

Example of standing wave!



Impedance of the load

- **We can estimate the load impedance using**

Reflection constant

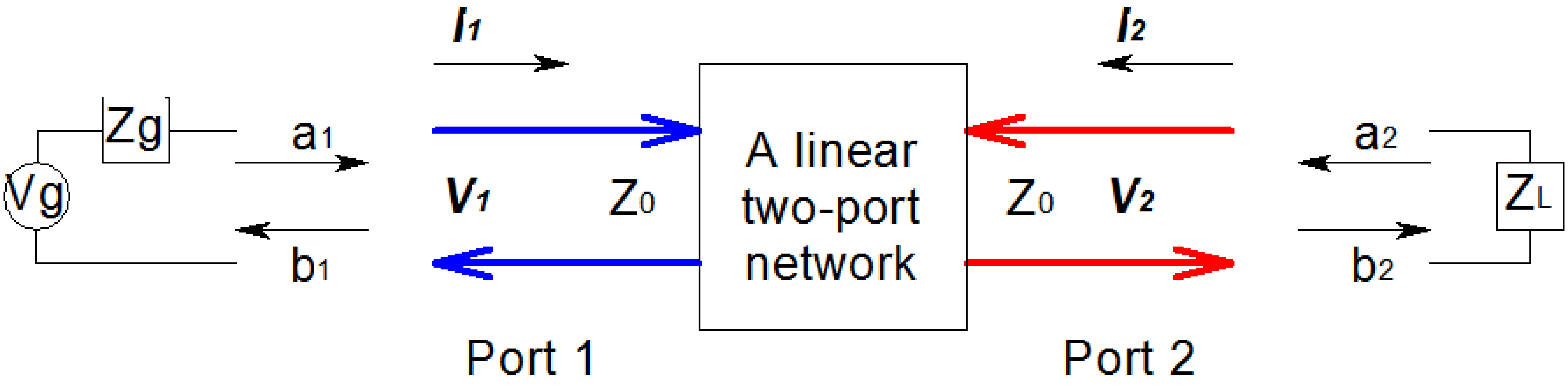
$$Z_r = Z_0 \frac{1+\rho}{1-\rho}$$

SWR

$$z_r = \frac{Z_r}{Z_0} = \frac{1+|\rho|e^{j\varphi}}{1-|\rho|e^{j\varphi}} = \frac{(S+1)+(S-1)e^{j(2\beta d_{\min}+\pi)}}{(S+1)-(S-1)e^{j(2\beta d_{\min}+\pi)}}$$

$$= \frac{1-jS\tan\beta d_{\min}}{S-j\tan\beta d_{\min}}$$

Linear two port network



$$\begin{pmatrix} \mathbf{b}_1 \\ \mathbf{b}_2 \end{pmatrix} = \begin{pmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{pmatrix} \begin{pmatrix} \mathbf{a}_1 \\ \mathbf{a}_2 \end{pmatrix}$$

S-parameters

- **Input Reflection Coefficient with $Z_L=Z_0$**

$$S_{11} = \left.\frac{\mathbf{b}_1}{\mathbf{a}_1}\right|_{\mathbf{a}_2=0}$$

Input match

- **Output Reflection Coefficient with $Z_G=Z_0$ and $V_G=0$**

$$S_{22} = \left.\frac{\mathbf{b}_2}{\mathbf{a}_2}\right|_{\mathbf{a}_1=0}$$

Output match

- **Forward Transmission Coefficient with $Z_L=Z_0$**

$$S_{21} = \left.\frac{\mathbf{b}_2}{\mathbf{a}_1}\right|_{\mathbf{a}_2=0}$$

Gain or loss

- **Reverse Transmission Coefficient with $Z_G=Z_0$ and $V_G=0$**

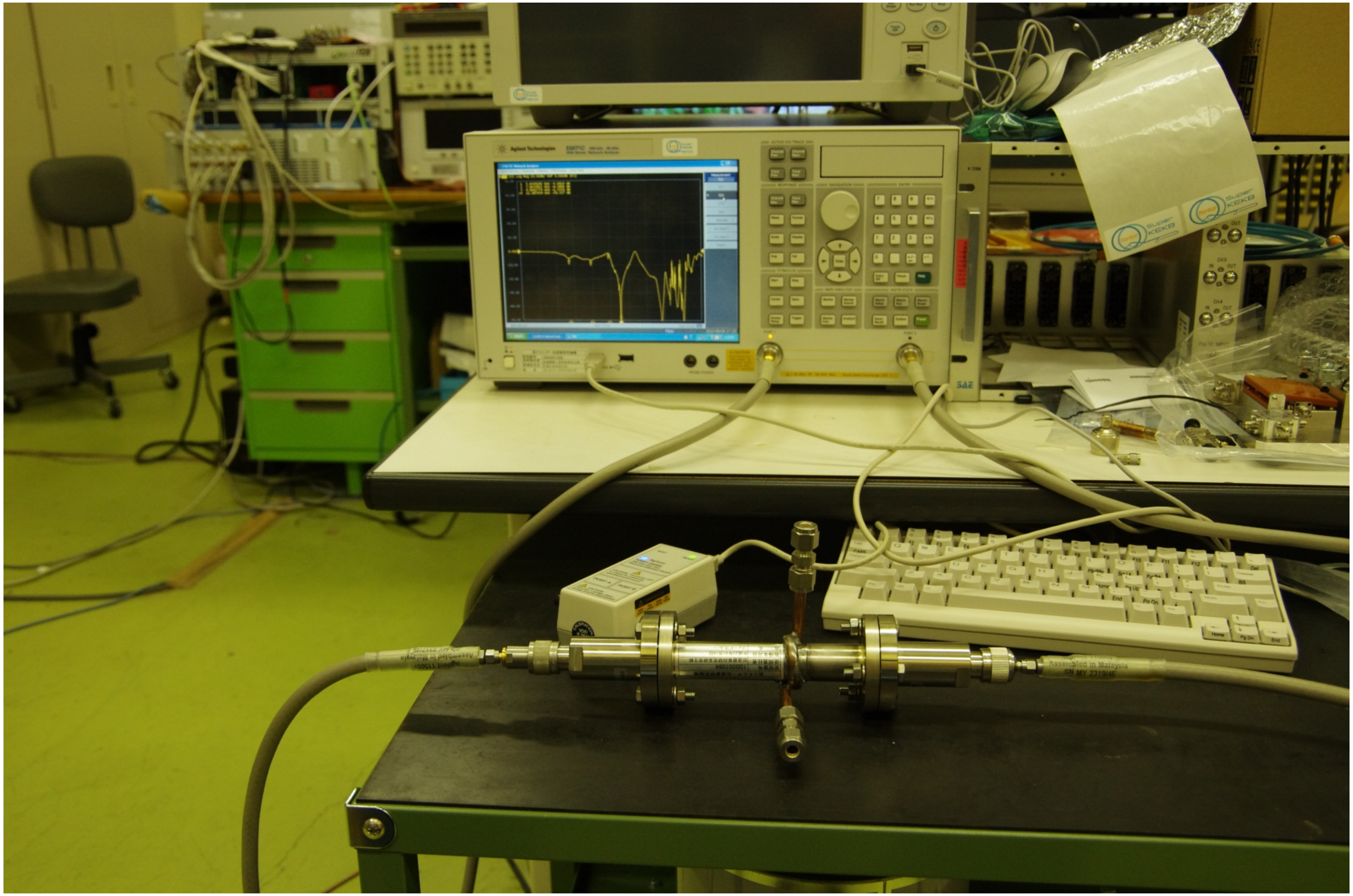
$$S_{12} = \left.\frac{\mathbf{b}_1}{\mathbf{a}_1}\right|_{\mathbf{a}_2=0}$$

Isolation

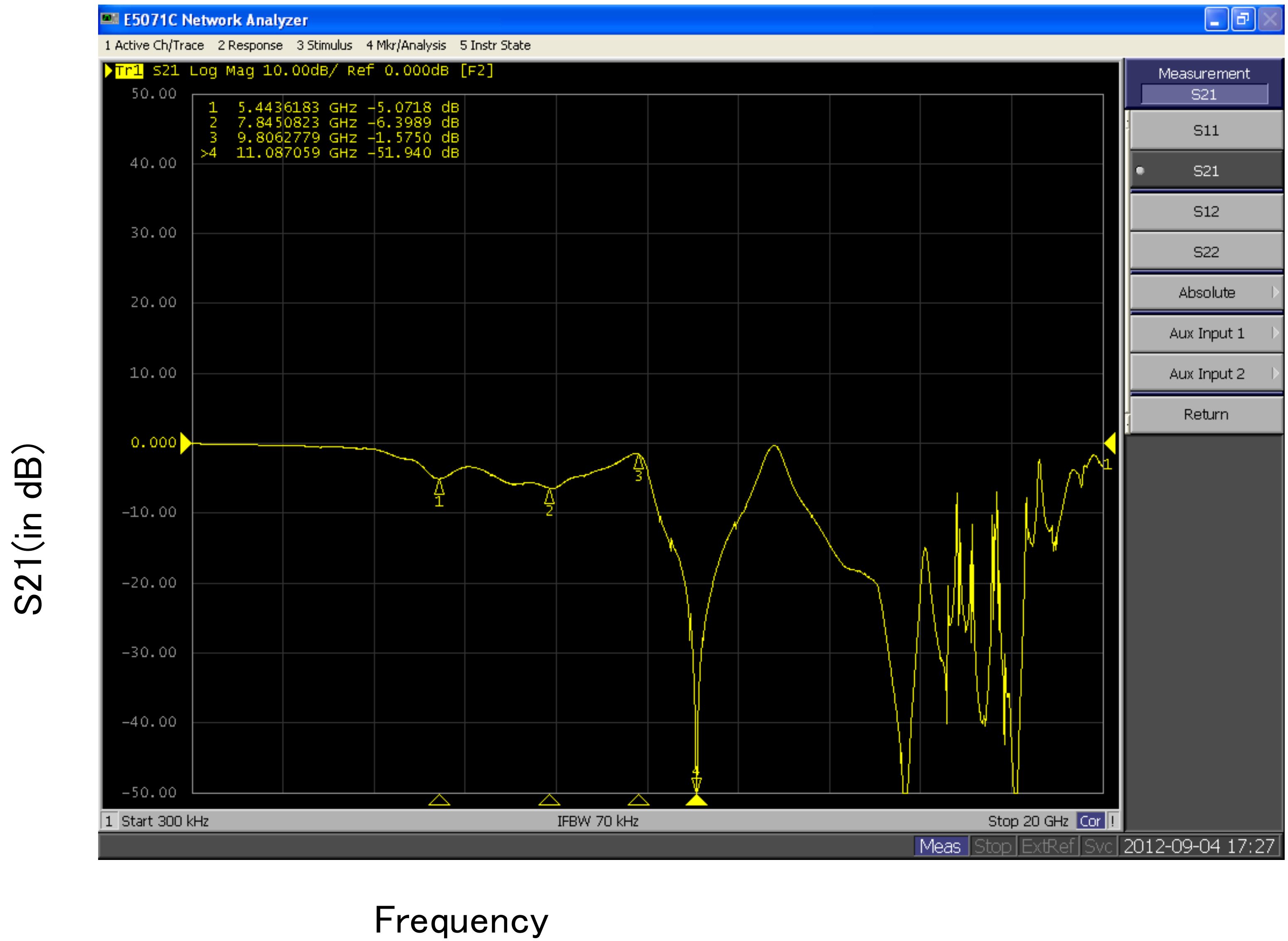
Why Use S-Parameters?

- **relatively easy to obtain at high frequencies**
  - measure voltage traveling waves with a vector network analyzer
  - don't need shorts/opens which can cause active devices to oscillate or self-destruct
- **relate to familiar measurements (gain, loss, reflection coefficients...)**
- **can cascade S-parameters of multiple devices to predict system performance**
- **can compute H, Y or Z parameters from S-parameters if desired**
- **can easily import and use S-parameter files in electronic-simulation tools**

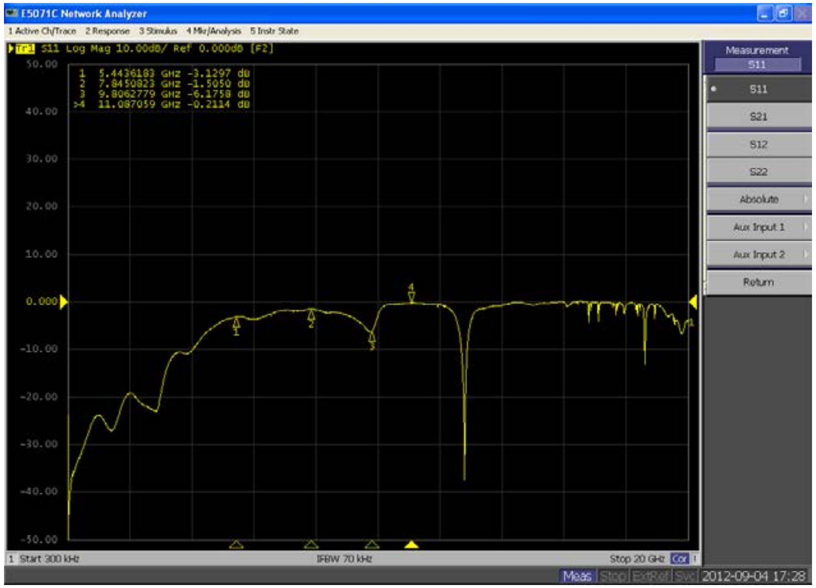
RF Network Analyzer

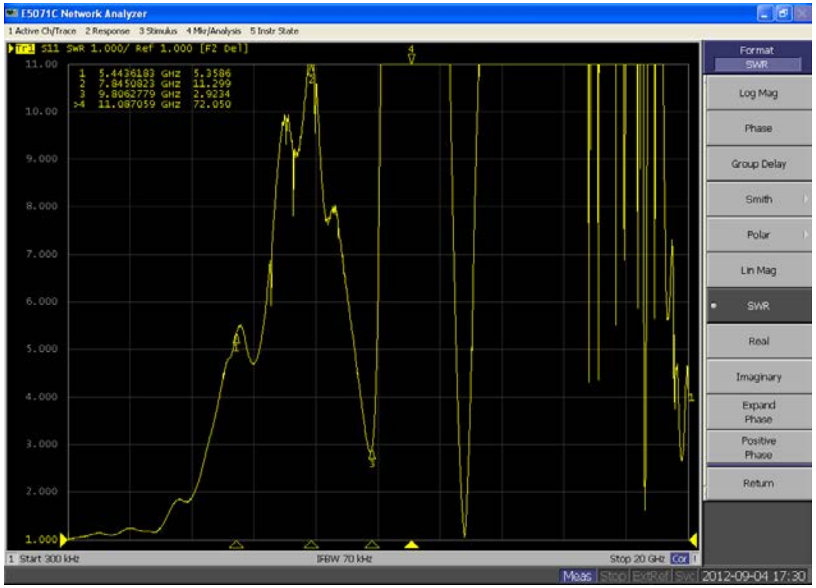


S21


E5071C Network Analyzer
1 Active Ch/Trace 2 Response 3 Stimulus 4 Mkr/Analysis 5 Instr State
Tr1 S21 Log Mag 10.00dB/ Ref 0.000dB [F2]
1 5.4436183 GHz -5.0718 dB
2 7.8450823 GHz -6.3989 dB
3 9.8062779 GHz -1.5750 dB
>4 11.087059 GHz -51.940 dB
50.00
40.00
30.00
20.00
10.00
0.000
-10.00
-20.00
-30.00
-40.00
-50.00
Measurement
S21
S11
S21
S12
S22
Absolute
Aux Input 1
Aux Input 2
Return
1 Start 300 kHz
IFBW 70 kHz
Stop 20 GHz
Cor
Meas
Stop
ExtRef
Svc
2012-09-04 17:27
S21(in dB)
Frequency

S11 and SWR(VSWR)



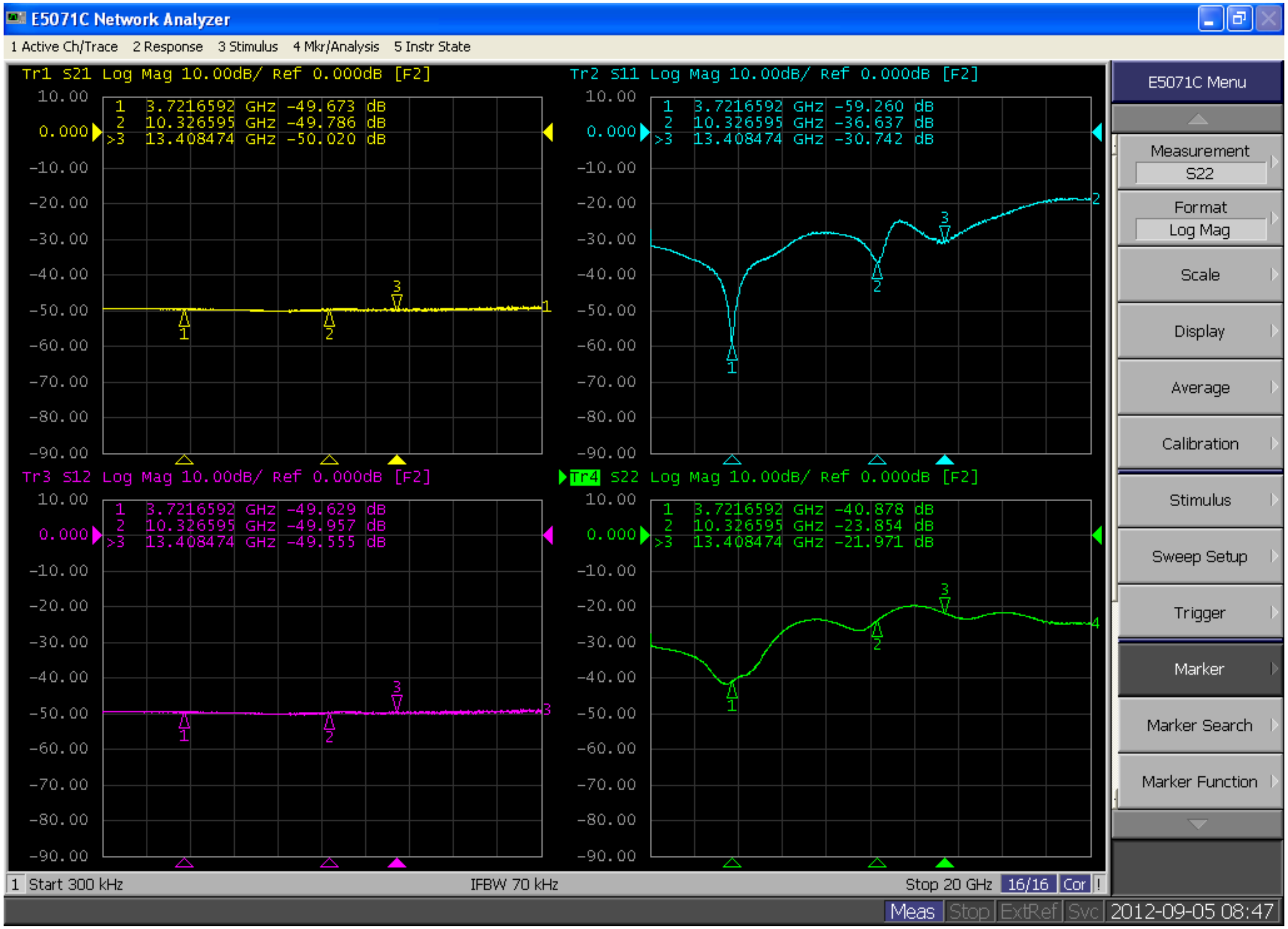


- **Return loss**

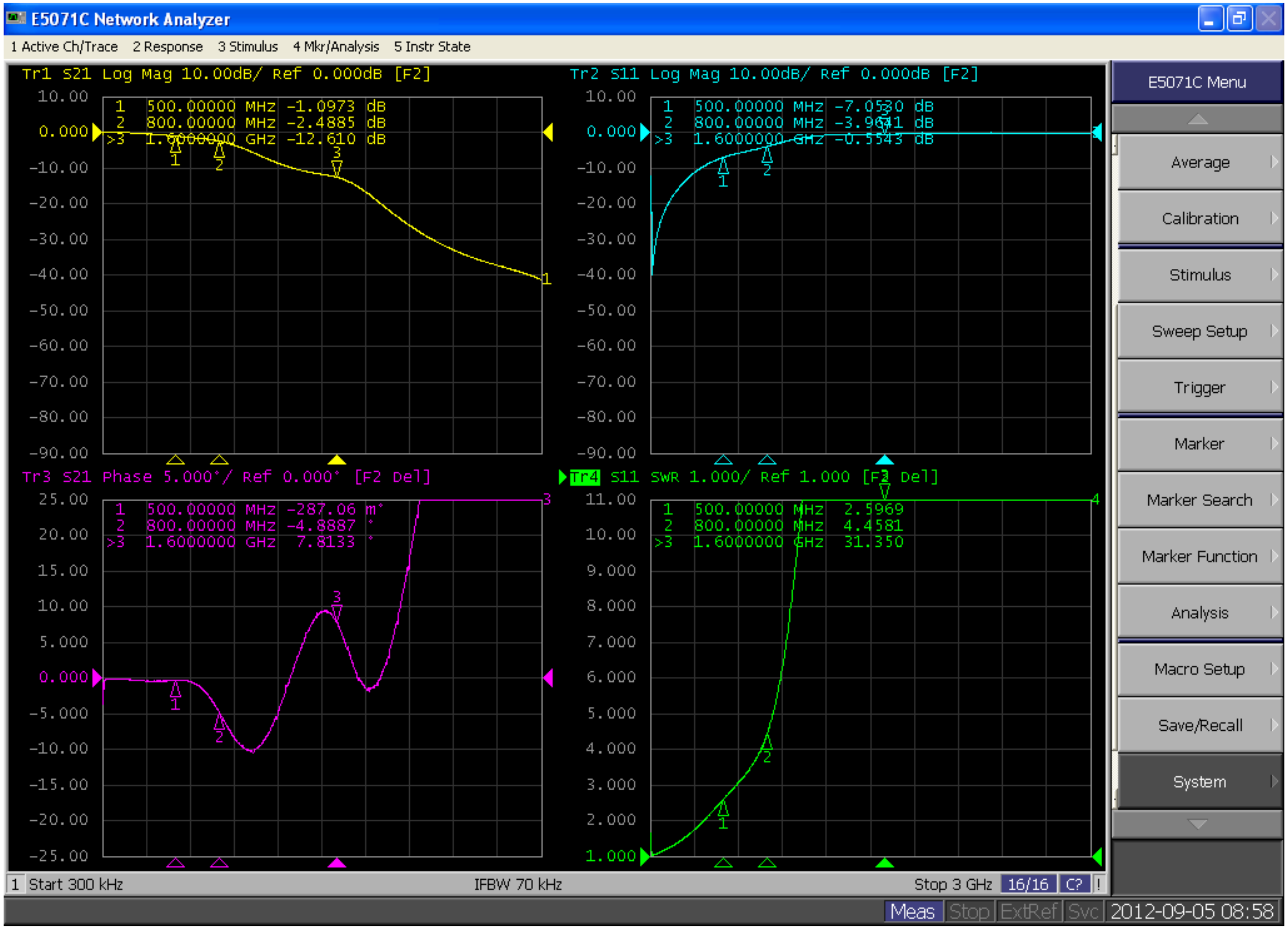
$$\left|20\log_{10}|S_{11}|\right| \mathrm{dB}$$

$$SWR_{input} = \frac{1+|S_{11}|}{1-|S_{11}|}$$

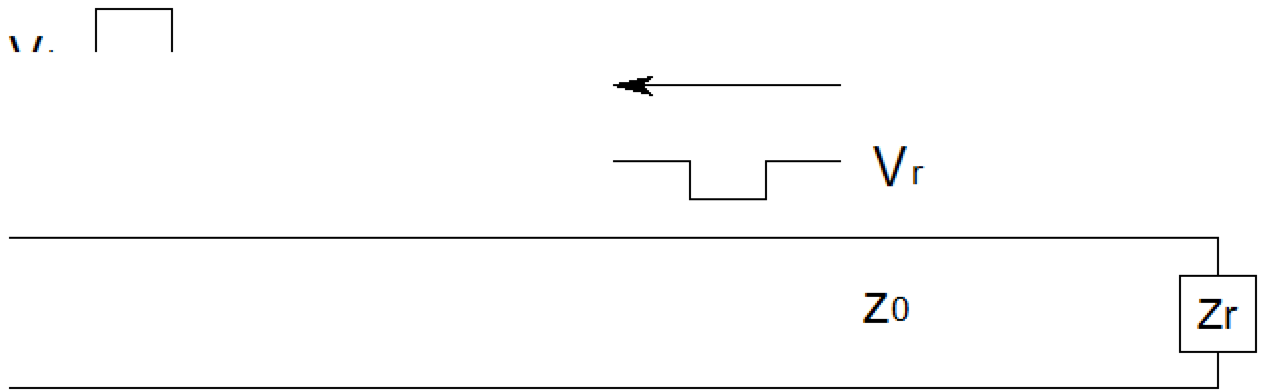
Example (50dB attenuator)



Example (800MHz Bessel LPF)



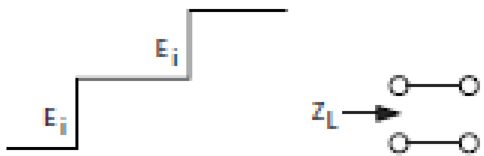
Time domain behavior--TDR



- **Using voltage ratio between forward and reflecting wave**

$$Z_r = \frac{1+\rho}{1-\rho} Z_0$$

$$\rho = \frac{V_r}{V_i}$$



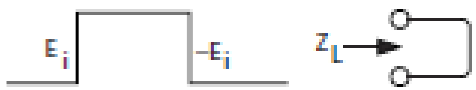
(A) Open Circuit Termination ($Z_L = \infty$)

(A) $E_r = E_i$

Therefore $\frac{Z_L - Z_o}{Z_L + Z_o} = +1$

Which is true as $Z_L \rightarrow \infty$

$\therefore$ Z = Open Circuit



(B) Short Circuit Termination ($Z_L = 0$)

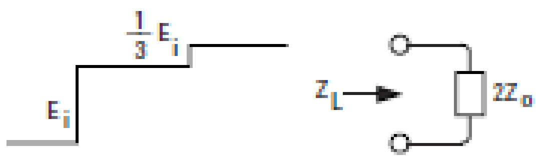
(B) $E_r = E_i$

Therefore $\frac{Z_L - Z_o}{Z_L + Z_o} = -1$

Which is only true for finite Z

When $Z_L = 0$

$\therefore$ Z = Short Circuit

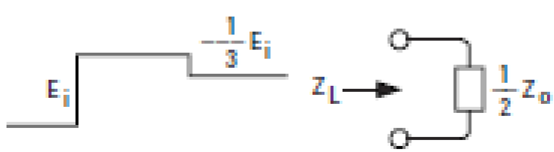


(C) Line Terminated in $Z_L = 2Z_o$

(C) $E_r = +\frac{1}{3} E_i$

Therefore $\frac{Z_L - Z_o}{Z_L + Z_o} = +\frac{1}{3}$

and $Z_L = 2Z_o$



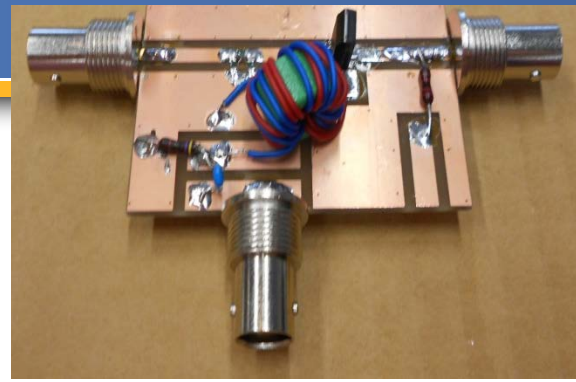
(D) Line Terminated in $Z_L = \frac{1}{2} Z_o$

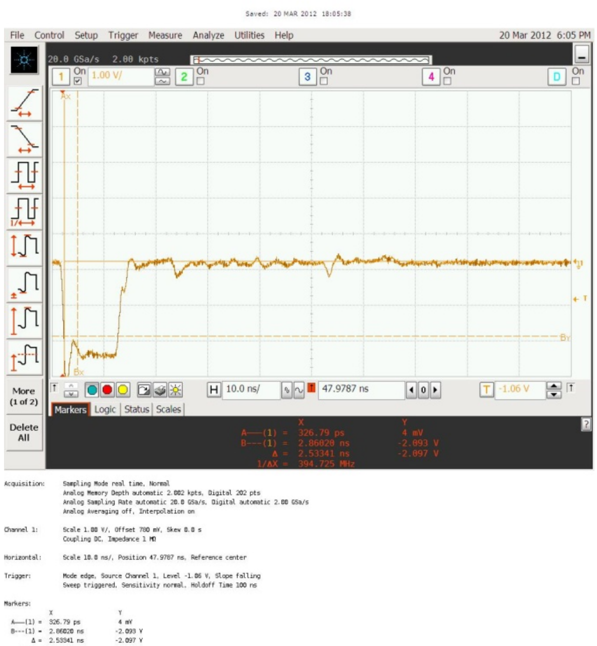
(D) $E_r = -\frac{1}{3} E_i$

Therefore $\frac{Z_L - Z_o}{Z_L + Z_o} = -\frac{1}{3}$

and $Z_L = \frac{1}{2} Z_o$

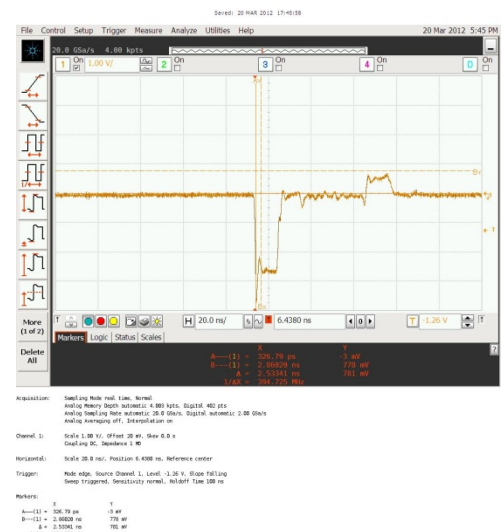
Science Camp 2011 (for High School students)





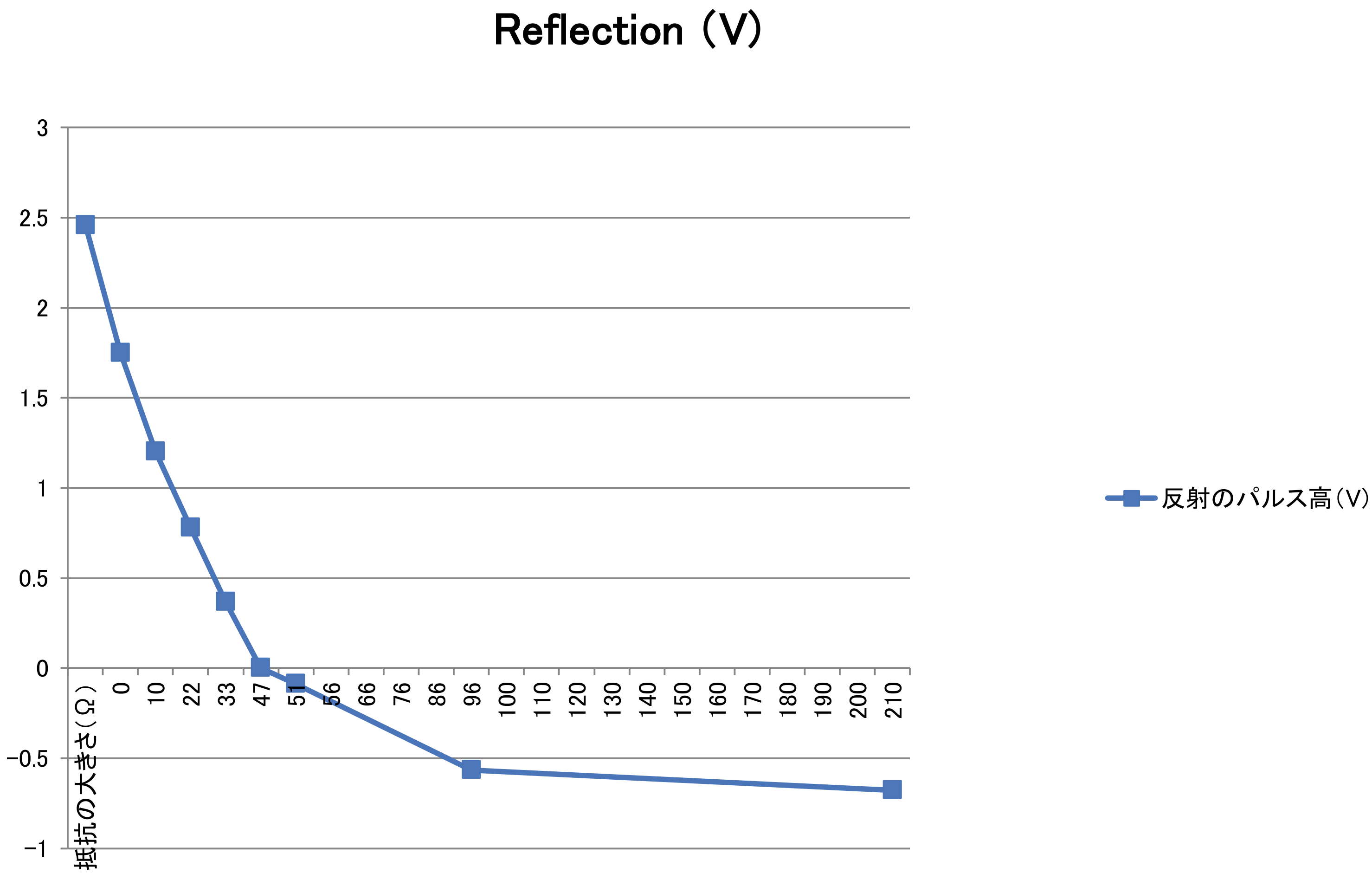
51Ω

470Ω

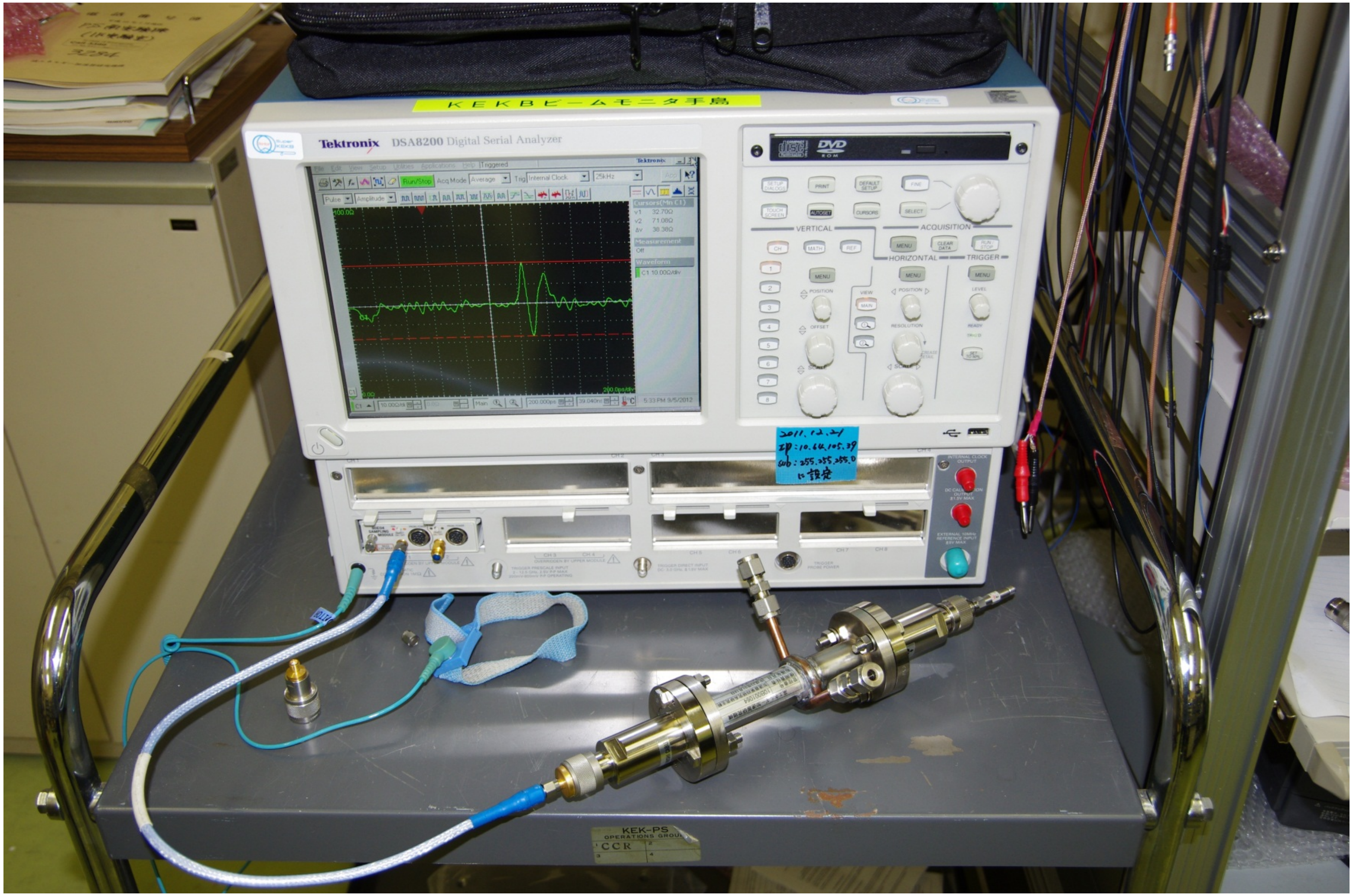


33Ω

Matching of 50-ohm line



Real TDR


Tektronix
DSA8200 Digital Serial Analyzer
KEKBビームモニタ手島
KEK-PS
OPERATIONS GROUP
CCR

Tips

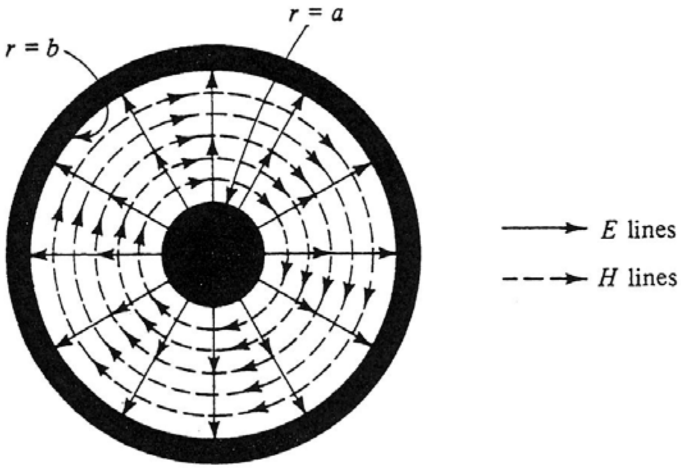
- **Good matched two-ports (such as J-J structure) is needed to measure the S-parameters of the feedthrough structure.**
  - For the TDR measurements, open structure (button or rod on vacuum side) might usually be OK

Ideal feedthrough?

- **Mechanical**
  - Completely satisfy required mechanical toughness
  - Satisfy vacuum requirements
- **Frequency domain**
  - S21 (and S12) ~1 (0dB)
  - S11 (and S22)~ −inf dB
- **Time domain**
  - Impedance=50 Ohm, completely matched structure

Size of the feedthrough

- **Which connectors do you want to use?**
  - N?,SMA?,BNC?,7/16-DIN?,7/8-EIA?



$$Z_0 = 60\sqrt{\frac{\mu_R}{\varepsilon_R}}\ln\frac{b}{a}$$

Attenuation Length

$$\alpha \approx \alpha_c + \alpha_d$$

$$\alpha_c = 13.6\frac{\delta_s\sqrt{\varepsilon_R}\{1+(b/a)\}}{\lambda_0 b\ln(b/a)},$$

$$\alpha_d = 27.3\frac{\sqrt{\varepsilon_R}}{\lambda_0}\tan\delta$$

Higher-mode propagation in coaxial lines.

- TE11mode

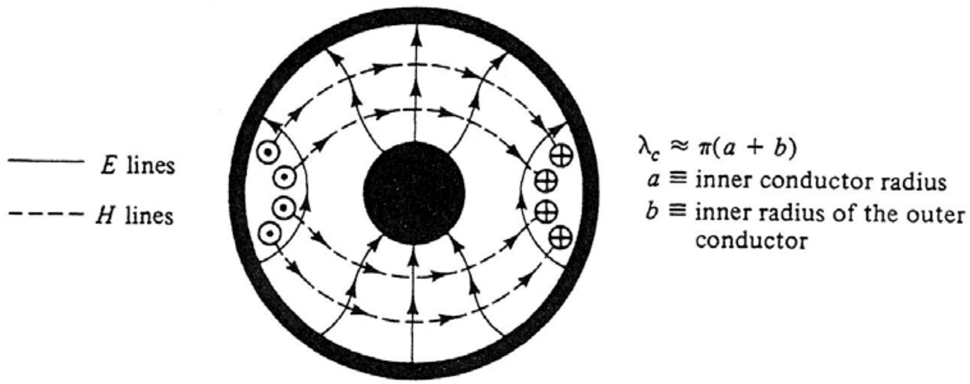
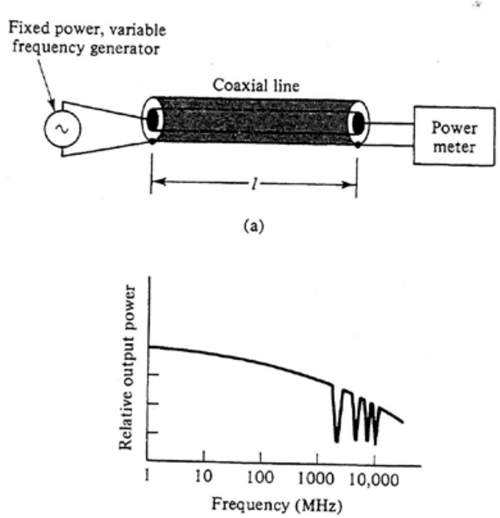


Figure 5–3 The electromagnetic field pattern for the TE_{11} mode in a coaxial line.

$$\lambda_c \approx \pi(a+b)$$

$$f_c \approx \frac{c}{\pi(a+b)\sqrt{\varepsilon_R}}$$



- Type-N:18GHz
- SMA: 34GHz

- RG-223:˜30GHz
- EIA 7/8”:˜6.8GHz

Connectors in the air

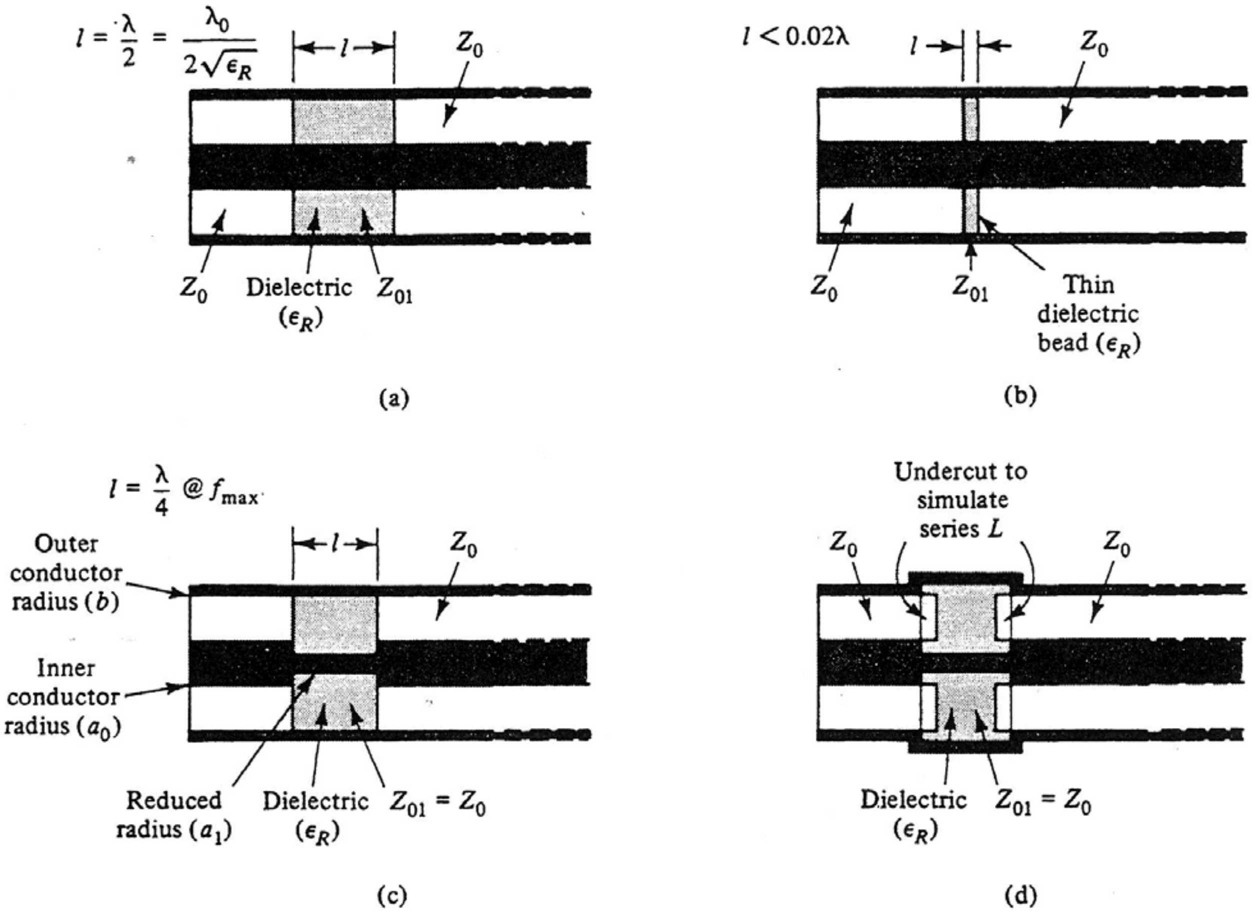


Figure 6–8 Four types of dielectric bead supports for coaxial lines.

$$Z_{01} = \frac{Z_0}{\sqrt{\varepsilon_R}}$$

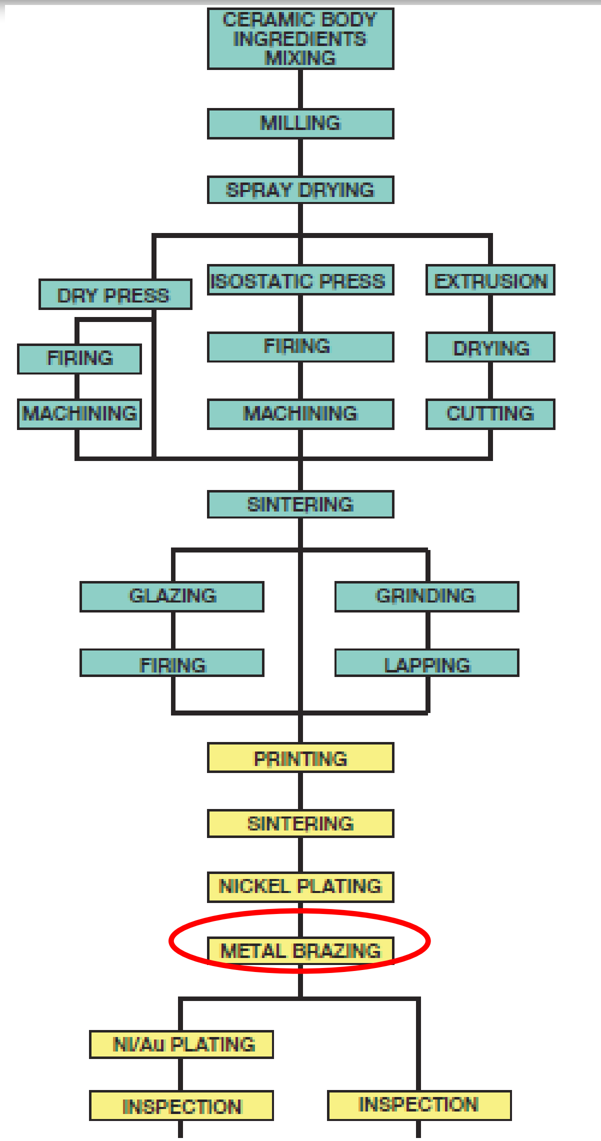
Feedthrough for vacuum

- **Vacuum seal (and support for inner conductor)**
  - Alumina ceramic (ε_R ~10), Si_3N_4(~8)
  - Glass (ε_R ~4–5)
    - Much larger than the support used in the air (~2)
- **Need to stand mechanical stress coming from**
  - Vacuum pressure
  - (huge) pressure when connecting the cable (or attenuator) to the feedthrough
  - Thermal stress
    - Baking
    - Heating by the beam power
- **Need to keep good RF contact under severe condition**
  - Heat cycle
  - Radiation, active gas

Outer/inner conductor

- **Kovar (Nickel–cobalt ferrous alloy)**
  - Designed to be compatible with the thermal expansion characteristics of borosilicate glass
  - Ferromagnetics: Not so good for use near strong magnet.
  - Thermal conductivity : Low
- **Ti**
  - Non-magnetic material
- **Cu, Al, Stainless steel..**
  - Also be usable. Consult your ceramic company.

Feedthrough process



Brazing temperature

- ~800 degC
- After brazing process, metal parts will be well annealed – original characteristics might be changed.
  - No spring action at all!

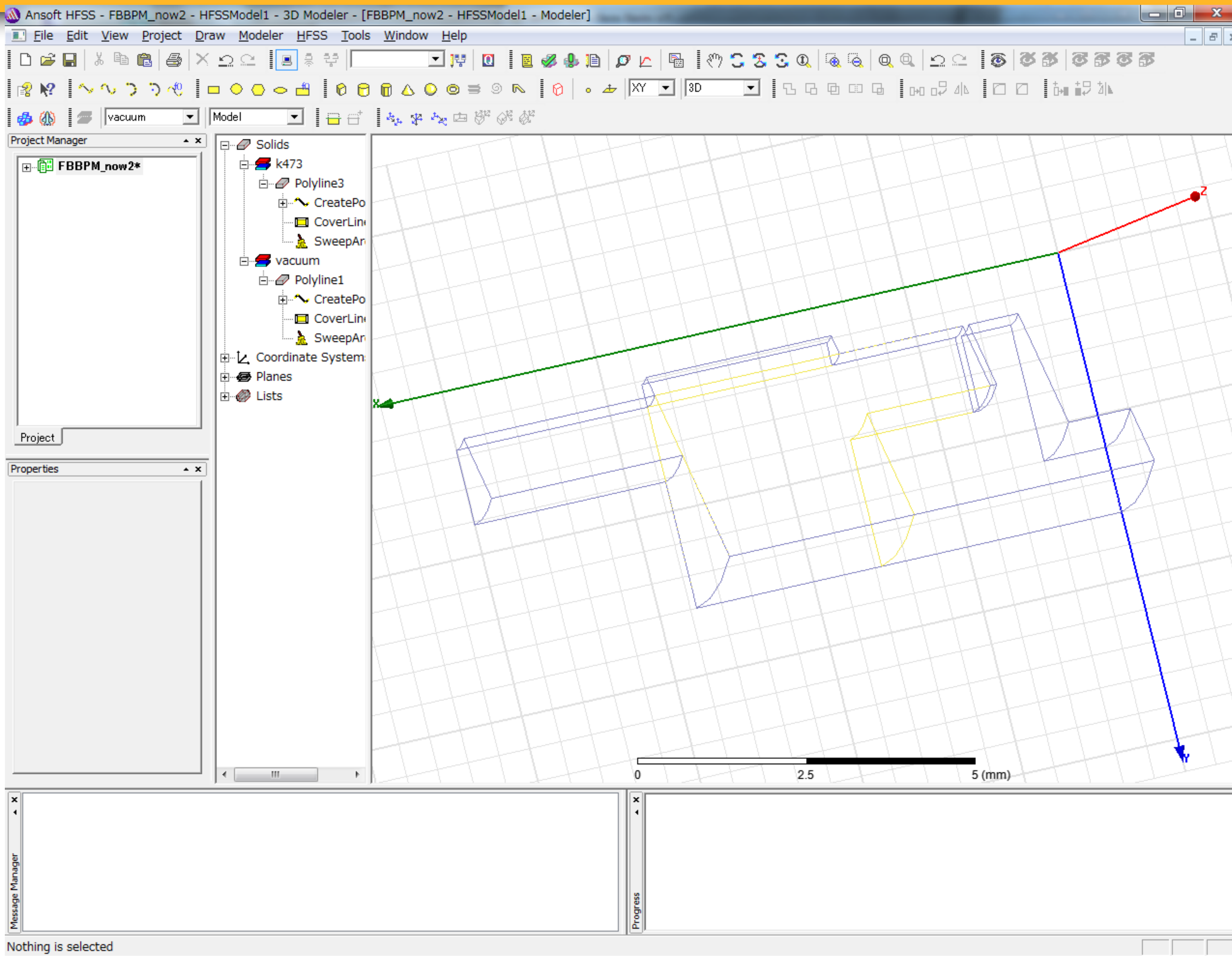
Braze to vacuum chamber OK?

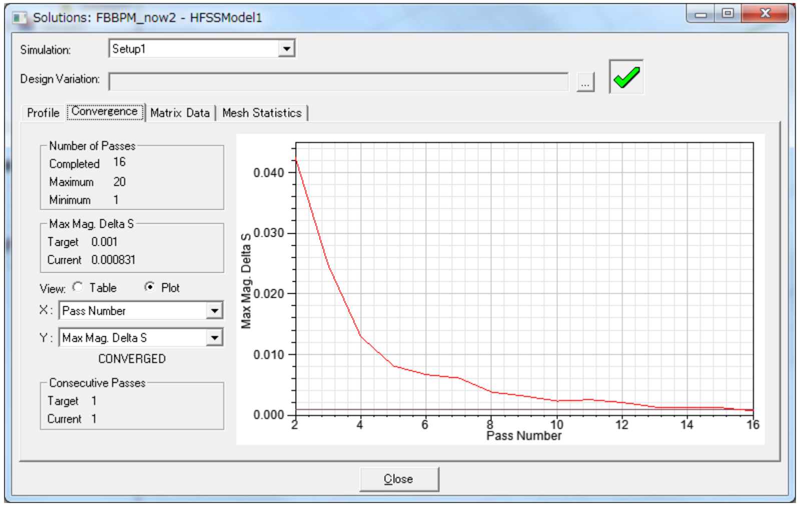
- Second (third?) brazing process
- There exist brazing materials with lower temperature
  - Not so easy to control the temperature

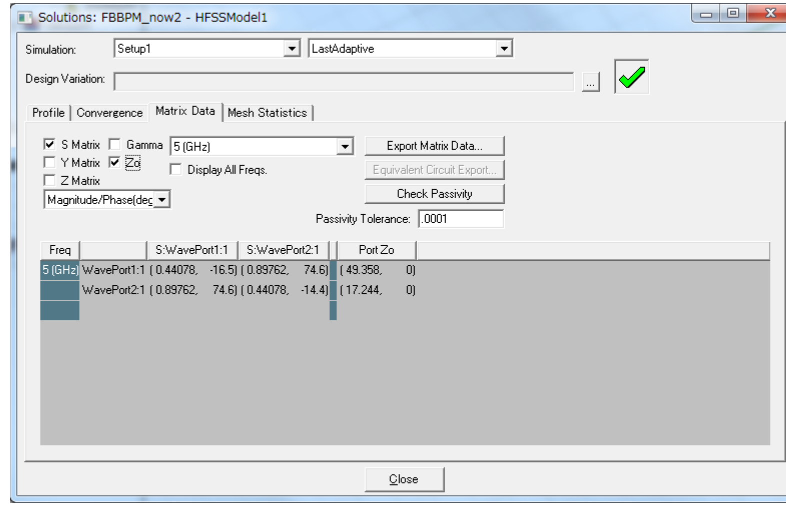
Frequency domain design

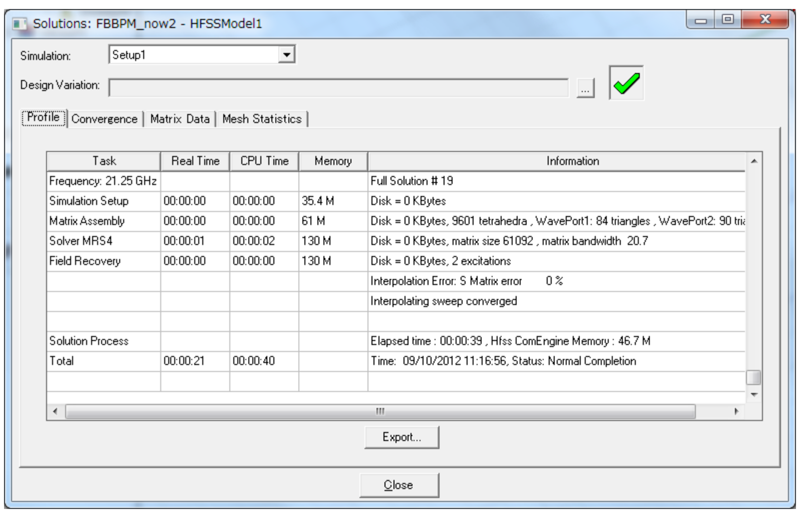
- **ANSYS (Ansoft) HFSS**
  - 3D full-wave electromagnetic field simulator
  - Multiple state-of the-art solver (finite element method or integral equation method)
  - calculate S-parameters, field patterns, eigen values, impedances..
  - Good user interface, Good interface to other tools such as ANSYS, etc.
  - Automatic mesh handing
  - (Very) Fast simulation speed

Example

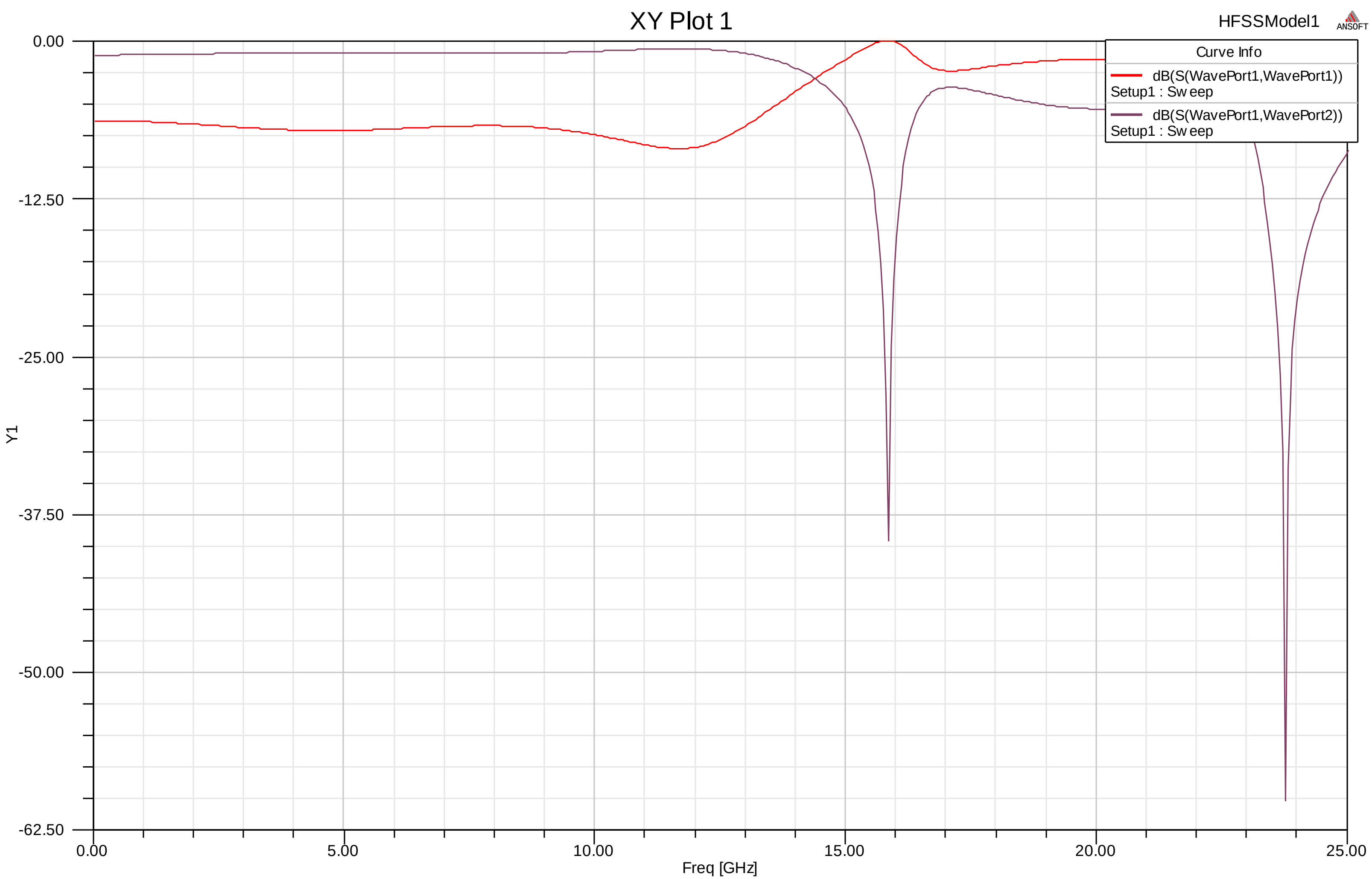

Ansoft HFSS - FBBPM_now2 - HFSSModel1 - 3D Modeler - [FBBPM_now2 - HFSSModel1 - Modeler]
File Edit View Project Draw Modeler HFSS Tools Window Help
vacuum
Model
XY
3D
Project Manager
FBBPM_now2*
Project
Properties
Solids
k473
Polyline3
CreatePo
CoverLin
SweepAr
vacuum
Polyline1
CreatePo
CoverLin
SweepAr
Coordinate System
Planes
Lists
X
Y
Z
0
2.5
5 (mm)
Message Manager
Progress
Nothing is selected


Solutions: FBBPM_now2 - HFSSModel1
Simulation: Setup1
Design Variation:
Profile | Convergence | Matrix Data | Mesh Statistics
Number of Passes
Completed 16
Maximum 20
Minimum 1
Max Mag. Delta S
Target 0.001
Current 0.000831
View: Table Plot
X: Pass Number
Y: Max Mag. Delta S
CONVERGED
Consecutive Passes
Target 1
Current 1
Max Mag. Delta S
0.040
0.030
0.020
0.010
0.000
2 4 6 8 10 12 14 16
Pass Number
Close

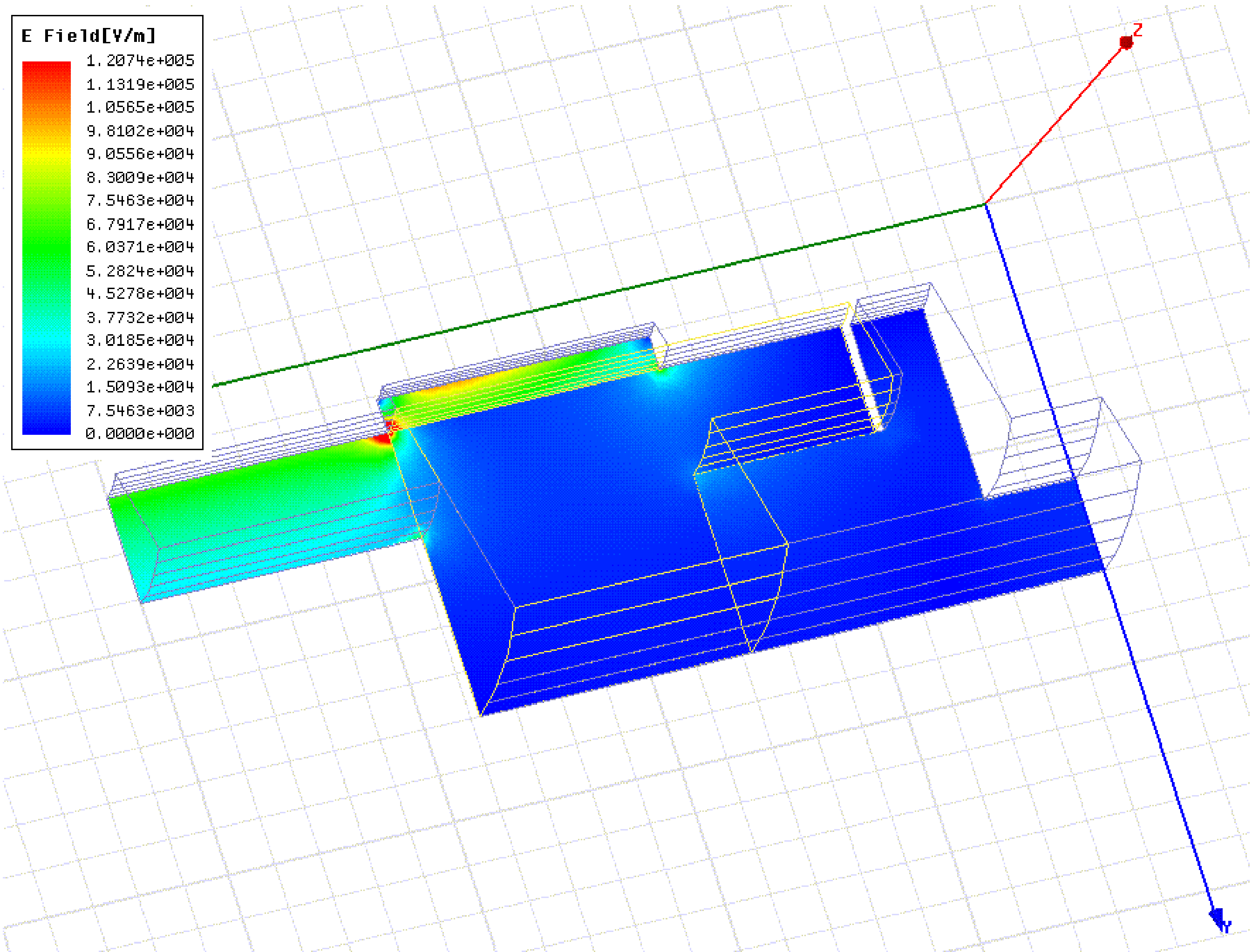

Solutions: FBBPM_now2 - HFSSModel1
Simulation: Setup1 LastAdaptive
Design Variation:
Profile | Convergence | Matrix Data | Mesh Statistics
S Matrix Gamma 5 (GHz) Export Matrix Data...
Y Matrix Zo Display All Freqs. Equivalent Circuit Export...
Z Matrix
Magnitude/Phase(deg Check Passivity
Passivity Tolerance: .0001
Freq S:WavePort1:1 S:WavePort2:1 Port Zo
5 (GHz) WavePort1:1 (0.44078, -16.5) (0.89762, 74.6) (49.358, 0)
WavePort2:1 (0.89762, 74.6) (0.44078, -14.4) (17.244, 0)
Close


Solutions: FBBPM_now2 - HFSSModel1
Simulation: Setup1
Design Variation:
Profile | Convergence | Matrix Data | Mesh Statistics
Task Real Time CPU Time Memory Information
Frequency: 21.25 GHz Full Solution # 19
Simulation Setup 00:00:00 00:00:00 35.4 M Disk = 0 KBytes
Matrix Assembly 00:00:00 00:00:00 61 M Disk = 0 KBytes, 9601 tetrahedra , WavePort1: 84 triangles , WavePort2: 90 tri
Solver MRS4 00:00:01 00:00:02 130 M Disk = 0 KBytes, matrix size 61092 , matrix bandwidth 20.7
Field Recovery 00:00:00 00:00:00 130 M Disk = 0 KBytes, 2 excitations
Interpolation Error: S Matrix error 0 %
Interpolating sweep converged
Solution Process Elapsed time : 00:00:39 , Hfss ComEngine Memory : 46.7 M
Total 00:00:21 00:00:40 Time: 09/10/2012 11:16:56, Status: Normal Completion
Export...
Close

(Fast) Frequency sweep



E-Field pattern



Time domain simulation

- **GdfidL Electromagnetic Field simulator**
  - Time dependent Fields in loss-free or lossy structure
  - Fields may be excited by port mode or relativistic line charge
  - Resonant fields in loss-free or lossy structure
- **Calculated result**
  - S-parameters, including power (voltage) value
  - Wake potentials including loss factor, impedance etc.
  - Q values and Shunt impedance
- **Need (some)large-scale parallel computing resources**
  - KEKB: 256 cores, 512GB Linux cluster
  - Text-base user interface, longer simulation time

Example of GdfidL input(1)

```
define(EL,1) define(MAG,2)
define(INF, 1000)

define(PipeRadius, 25.40e-3/2)
define(PipeStart, 100.0e-3)
define(PipeEnd,100.0e-3)
define(BpmAdd,13.5e-3)
define(STPSZE,0.1e-3)

-general
   outfile= /users/tobiyama/GD/bpm-CL22/temp/
   scratchbase =/users/tobiyama/GD/scratch/
-material
 material=10
 type=electric
 material=15
 type=normal, epsr=9.7, muer=1, kappa=0, mkappa=0
```

```
-mesh
  spacing=0.1e-3
  pxlow= 0
  pxhigh=(PipeRadius+BpmAdd-5*STPSZE)
  pylow= 0
  pyhigh=(PipeRadius+BpmAdd-5*STPSZE)
  pzlow=-PipeStart+5*STPSZE
  pzhigh=PipeEnd-5*STPSZE

  cxlow=magnetic, cxhigh=electric
  cylow=magnetic, cyhigh=electric
  czlow=electric, czhigh=electric

-brick
 material=EL
 xlow= -INF, xhigh=INF
 ylow= -INF, yhigh=INF
 zlow= -INF, zhigh=INF
 doit
```

Example of GdfidL input(2)

```
#
# cave beam pipe
#
-gbor
  material=0
  origin=(0,0,0)
  zprimedirection= (0,0,1)
  rprimedirection= (1,0,0)
  range= (0,360)

  clear

  point(-PipeStart,0)
  point(-PipeStart,PipeRadius)
  point(PipeEnd,PipeRadius)
  point(PipeEnd,0)
  point(-PipeStart,0)
  show=all
  doit
```

```
#
# bpm block
#
macro BpmBlock
define(Dist, @arg1)
define(Angle, (@arg2)*@pi/180)

define(BpmDiskRadius, 6e-3/2)
define(BpmRodRadius,1.8e-3/2)
define(BpmairRadius,1.1e-3/2)
define(BpmOutRadius1, 8e-3/2)
define(BpmOutRadius2, 4.1e-3/2)
define(BpmCera1Radius,4.1e-3/2)
define(BpmCera2Radius,8e-3/2)
define(BpmDiskLength,1e-3)
define(BpmRod1Length,2.9e-3)
define(BpmRod2Length,3e-3)
define(BpmRod3Length,6.1e-3)

define(Cerastart,1.9e-3)
define(Cera1Length,2e-3)
define(Cera2Length,3e-3)

define(DP1, (5e-
3+BpmDiskLength+BpmRod1Length+BpmRod2Length))
define(DP2, (DP1+Dist - 5e-3))
```

Example of GdfidL input(3)

```
#
-gccylinder
 material=0, radius=BpmOutRadius1,length = DP1
 origin=(cos(Angle)*(Dist - 5e-3), sin(Angle)*(Dist - 5e-3),  0)
 direction=(cos(Angle),sin(Angle),0)
 doit
-gccylinder
 material=0, radius=BpmOutRadius2
 length= BpmRod3Length
 origin=(cos(Angle)*(DP2),sin(Angle)*(DP2),  0)
 direction=(cos(Angle),sin(Angle),0)
 doit
#
# ceramic
#
-gccylinder
 material=15, radius=BpmCera1Radius,length=Cera1Length
 origin=(cos(Angle)*(Dist+Cerastart), sin(Angle)*(Dist+Cerastart),  0)
 direction=(cos(Angle),sin(Angle),0)
 doit
-gccylinder
 material=15, radius=BpmCera2Radius,length=Cera2Length
 origin=(cos(Angle)*(Dist+Cerastart+Cera1Length),¥
        sin(Angle)*(Dist+Cerastart+Cera1Length),  0)
 direction=(cos(Angle),sin(Angle),0)
 doit
```

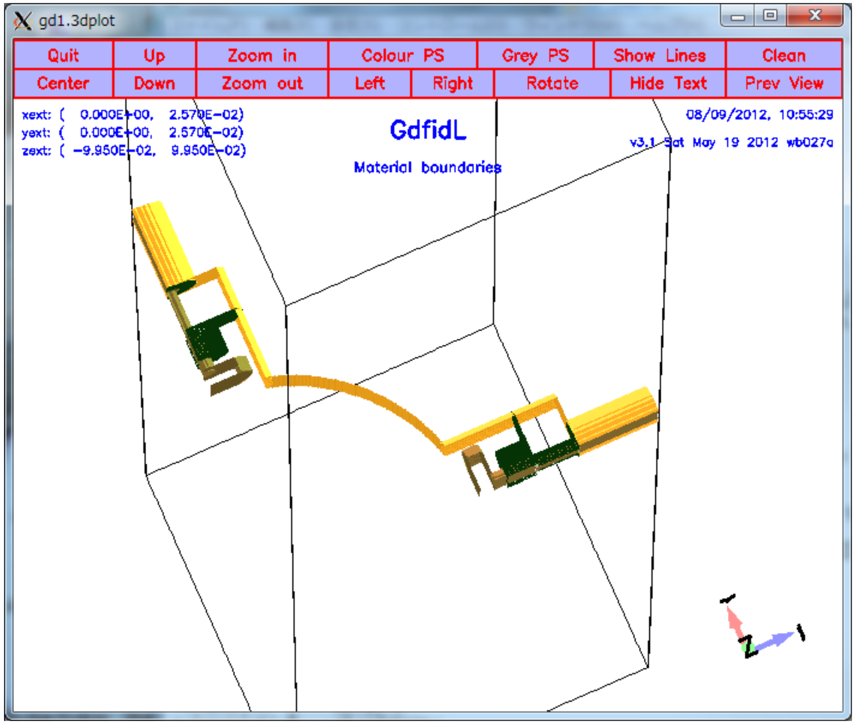
```
# air again
-gccylinder
 material=0, radius=BpmRodRadius,length =
(Cera1Length+Cera2Length)
 origin=(cos(Angle)*(Dist+Cerastart),sin(Angle)*(Dist-Cerastart)  0)
 direction=(cos(Angle),sin(Angle),0)
 doit
# bpm disk
-gccylinder
 material=10, radius=BpmDiskRadius,length=BpmDiskLength
 origin=(cos(Angle)*(Dist), sin(Angle)*(Dist), 0)
 direction=(cos(Angle),sin(Angle),0)
 doit
-gccylinder
 material=10, radius=BpmRodRadius, length=BpmRod1Length
 origin=(cos(Angle)*(Dist+BpmDiskLength),¥
 sin(Angle)*(Dist+BpmDiskLength),    0)
 direction=(cos(Angle),sin(Angle),0)
 doit


 ....still many definitions...

endmacro #BpmBlock
```

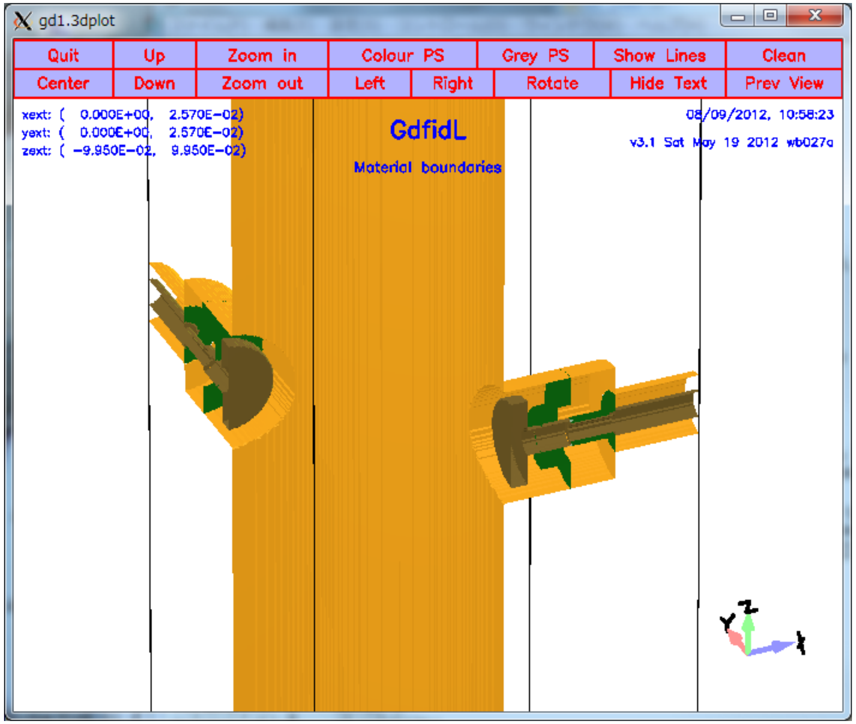
Example of GdfidL input(4)

```
call BpmBlock(13.2e-3,90)
call BpmBlock(13.2e-3,0)
call BpmBlock(13.2e-3,-90)
call BpmBlock(13.2e-3,180)

-fdtd
 -lcharge
    charge=1e-12
    sigma=6e-3
    xposition=0, yposition=0
    shigh=5
    showdata=no
 -ports
    name=beamlow, plane=zlow, modes=0, npml=40, doit
    name=beamhigh, plane=zhigh, modes=0, npml=40, doit
    name=bpmyp, plane=yhigh, modes=1, npml=15, doit
    name=bpmxp, plane=xhigh, modes=1, npml=15, doit

-fdtd
  doit
```

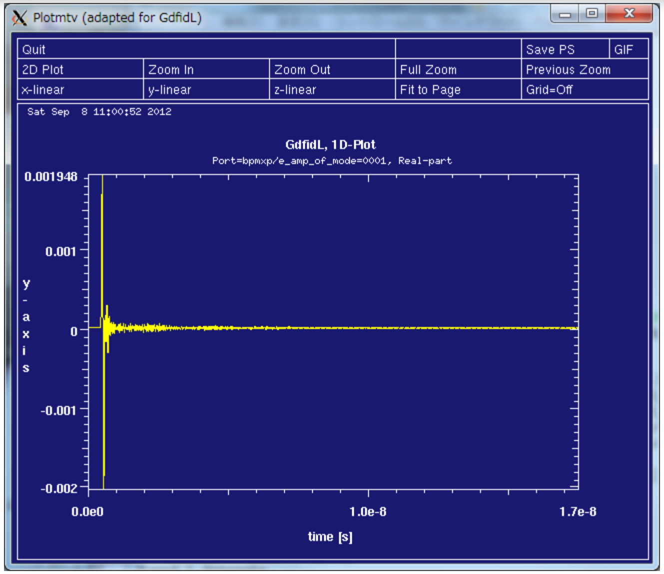
- **mesh 0.1mm**
- **bunch length 6mm**
- **beam=(0,0) [center]**
- **wake up to 5m**

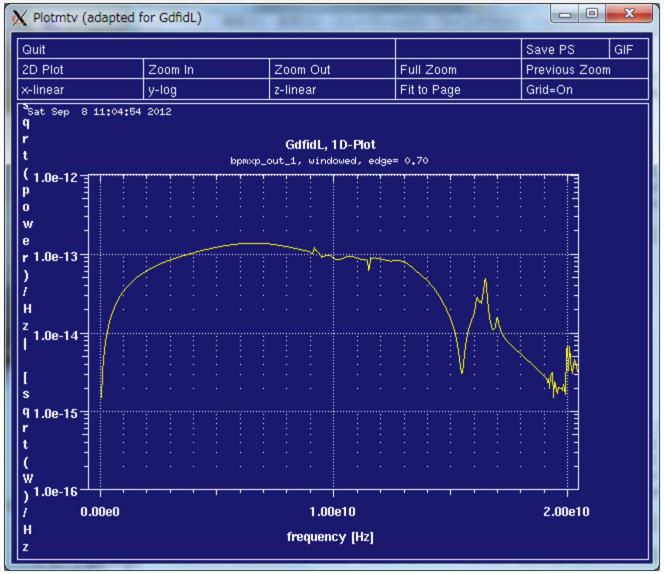
Model view

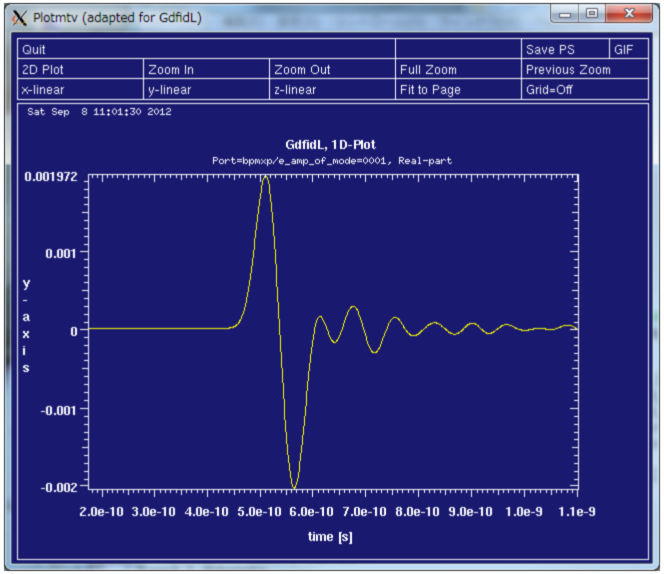

gd1.3dplot
Quit
Up
Zoom in
Colour PS
Grey PS
Show Lines
Clean
Center
Down
Zoom out
Left
Right
Rotate
Hide Text
Prev View
xext: (0.000E+00, 2.570E-02)
yext: (0.000E+00, 2.570E-02)
zext: (-9.950E-02, 9.950E-02)
GdfidL
Material boundaries
08/09/2012, 10:55:29
v3.1 Sat May 19 2012 wb027a


gd1.3dplot
Quit
Up
Zoom in
Colour PS
Grey PS
Show Lines
Clean
Center
Down
Zoom out
Left
Right
Rotate
Hide Text
Prev View
xext: (0.000E+00, 2.570E-02)
yext: (0.000E+00, 2.570E-02)
zext: (-9.950E-02, 9.950E-02)
GdfidL
Material boundaries
08/09/2012, 10:58:23
v3.1 Sat May 19 2012 wb027a

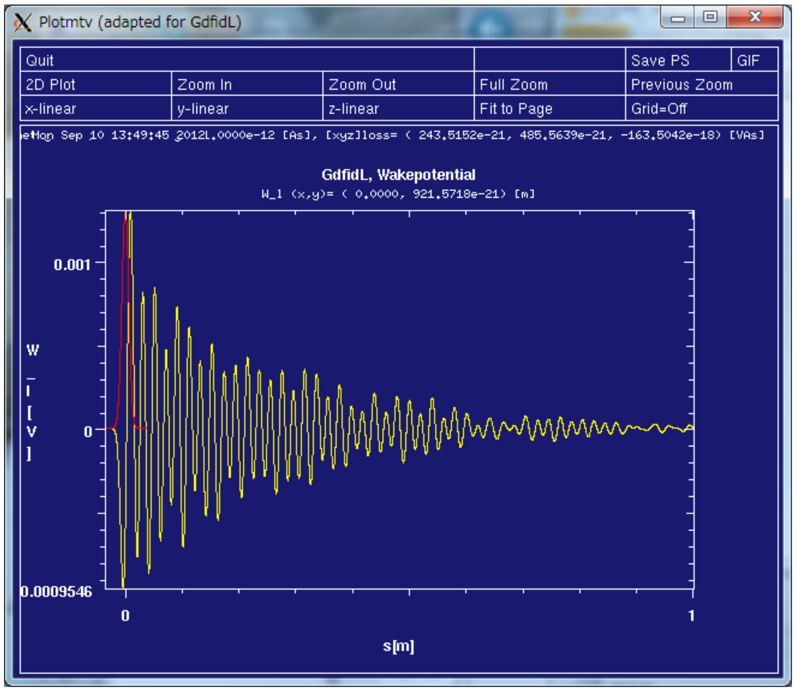
Post processing (using gd1.pp)

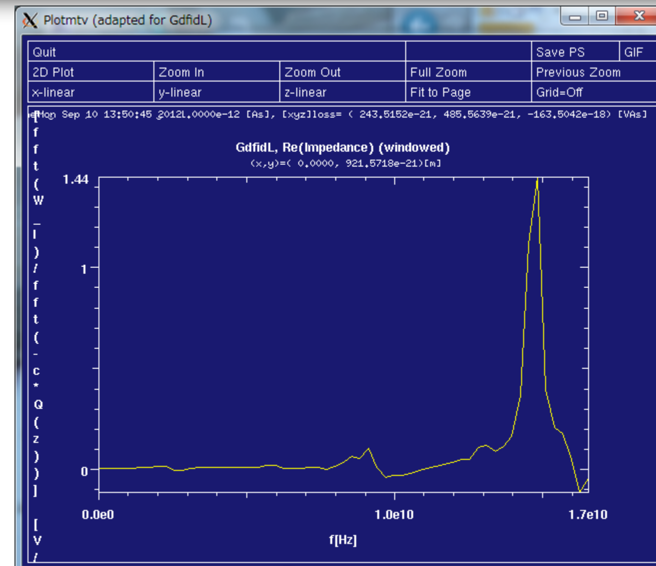






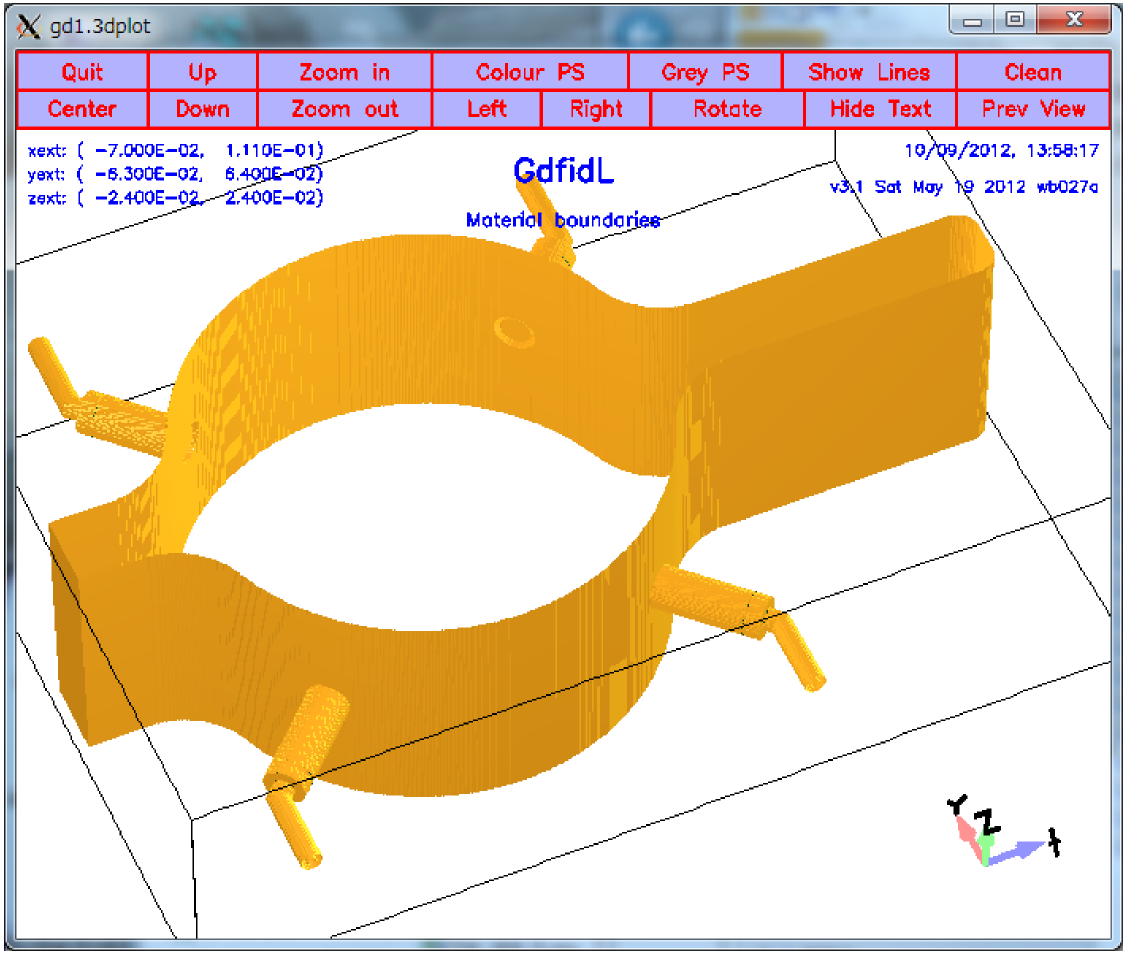
wakes, impedances



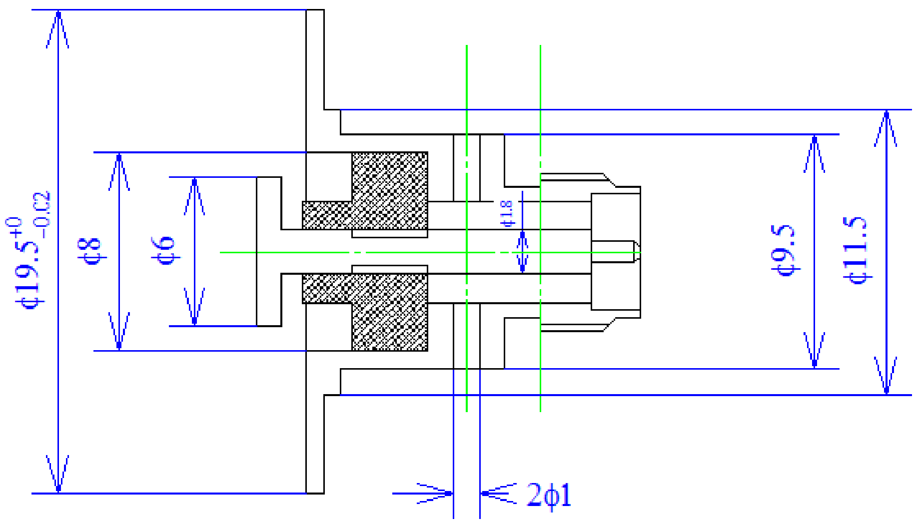


Tips

- **Ports must be placed orthogonally to the boundaries.**



Button electrode (KEKB-FB)

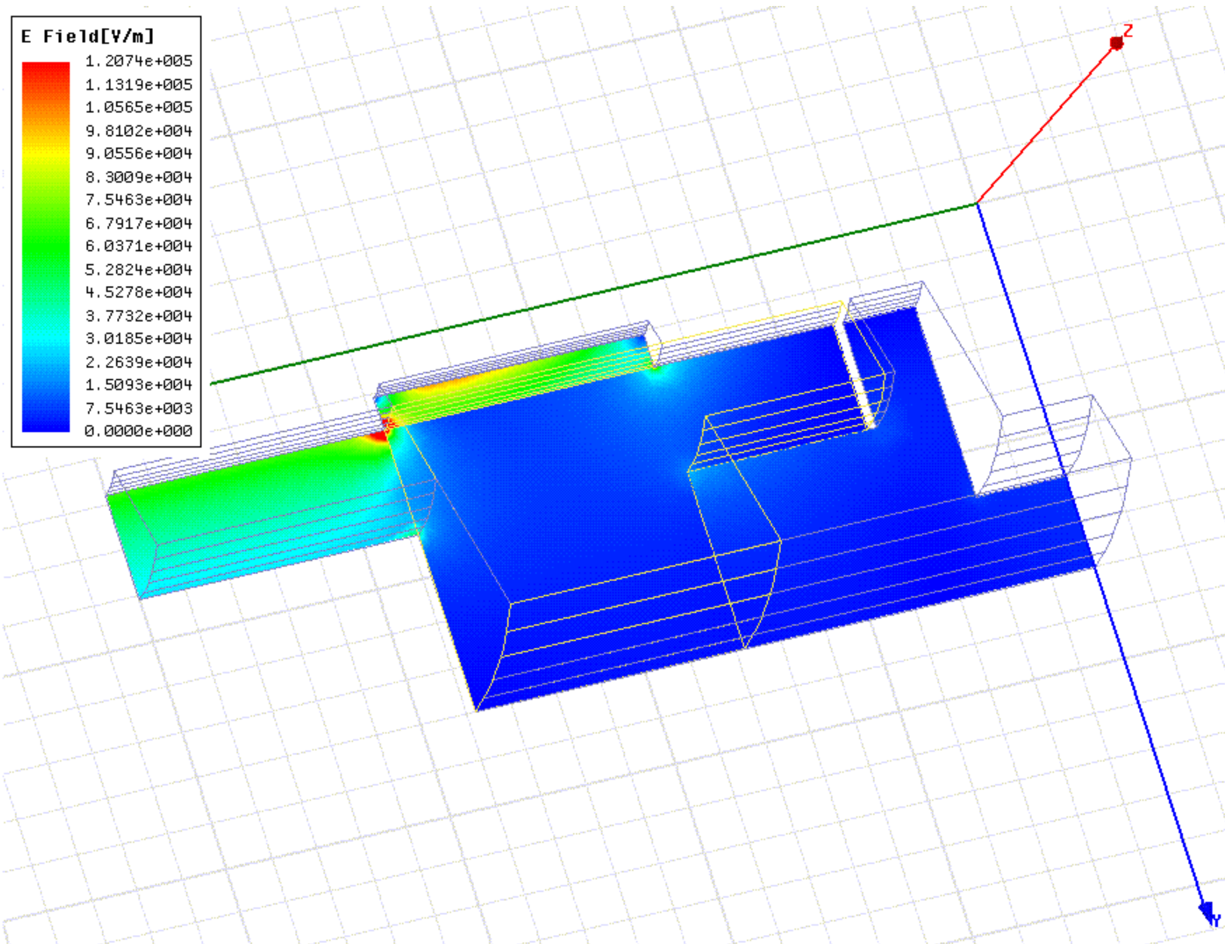


Feedback用SMAフィードスルーC型概略図
作図：飛山真理 19/Mar/2004
縮尺4:1

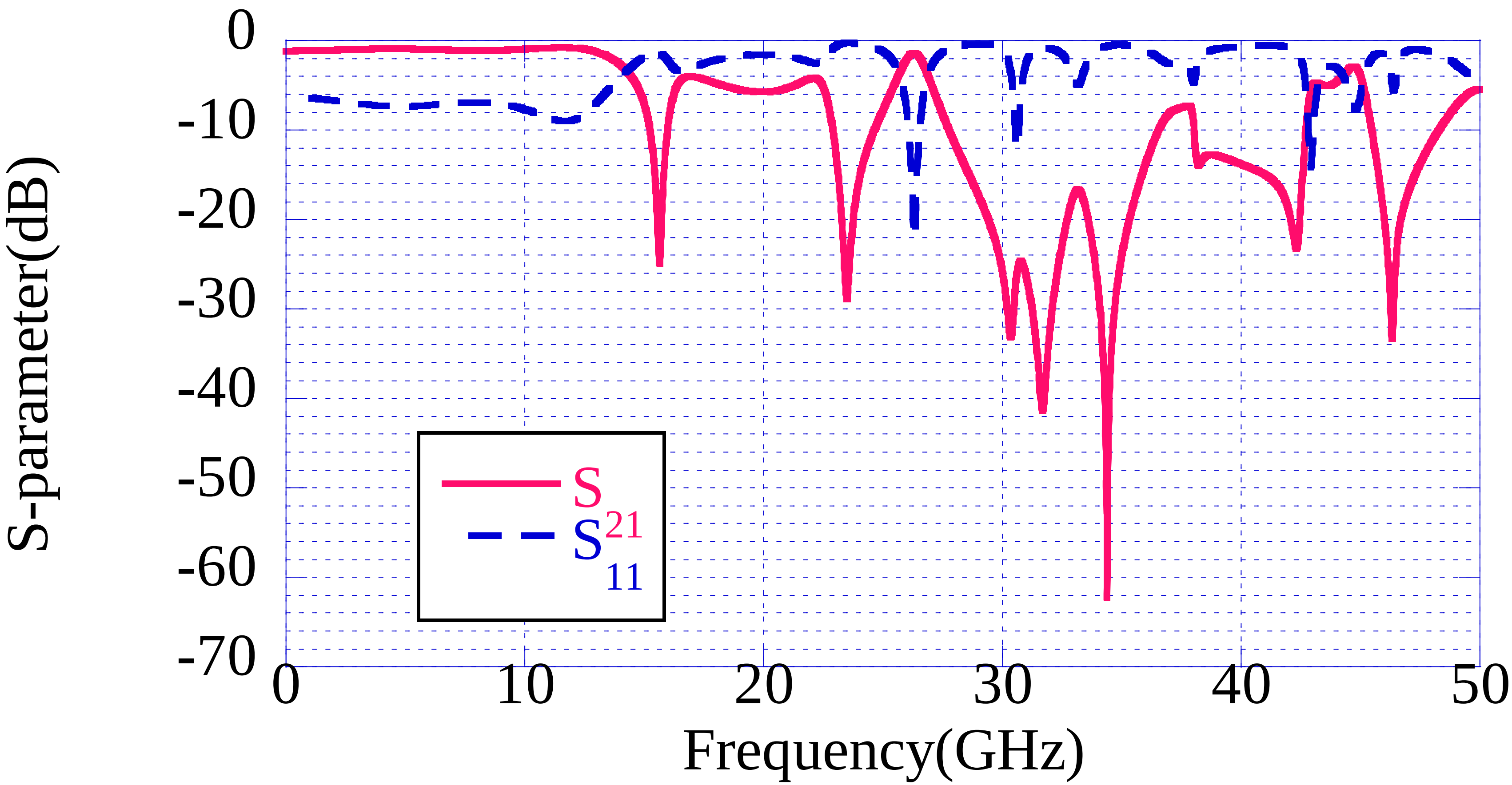
Tips

- **Using normal SMA-J connector (or N-J, too) usually encounter difficulty in RF contact at the split-pin of the center conductor due to brazing process – No spring action might be expected after the process.**
  - Using P-structure.. not easy to handle..
  - Use pin on the J-structure ("Reverse type J")
- **Gold-plating of at the RF connector is desirable**
  - Not easy to maintain the thickness of the gold during brazing process (Gold will be diffused into the bulk metal..)

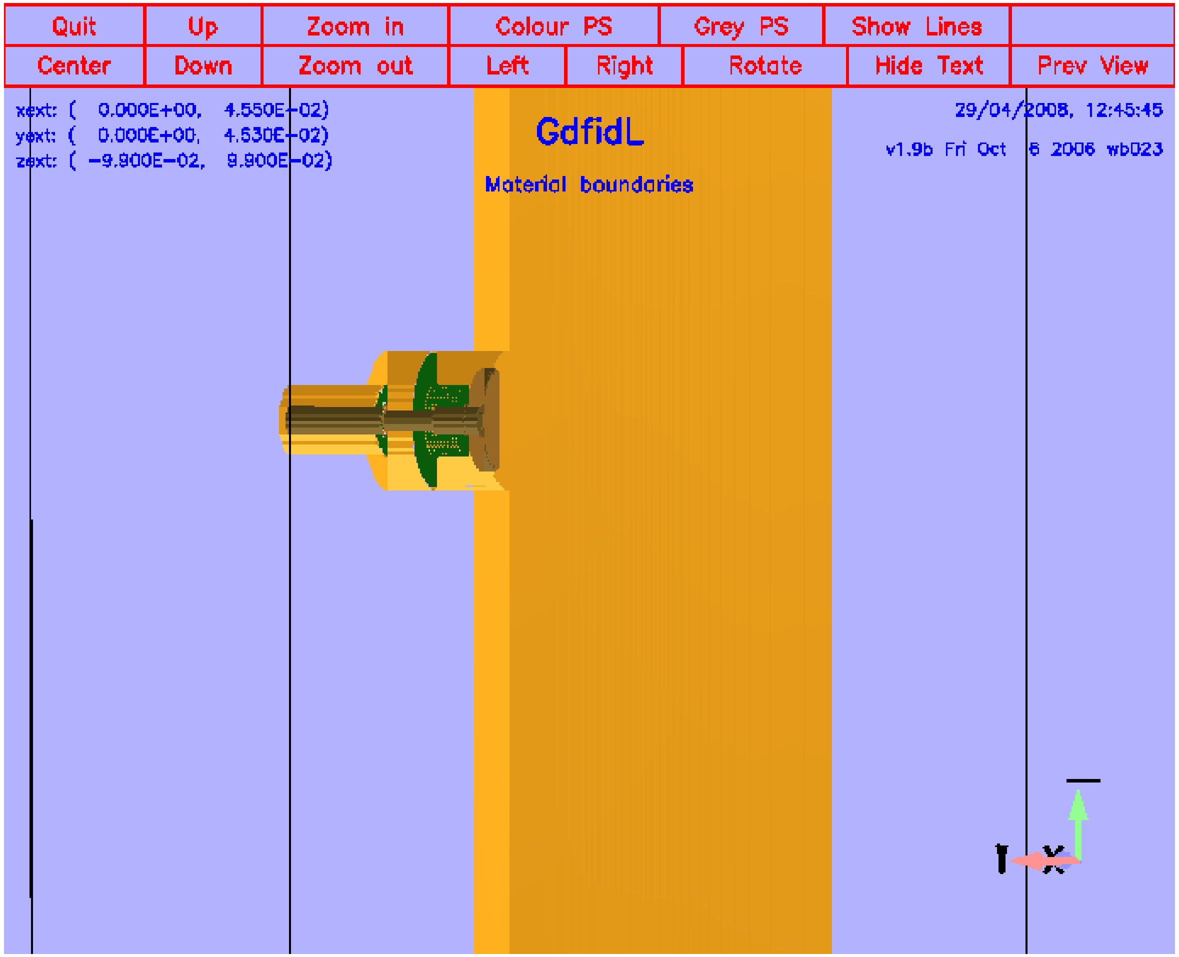
HFSS model


E Field[V/m]
1.2074e+005
1.1319e+005
1.0565e+005
9.8102e+004
9.0556e+004
8.3009e+004
7.5463e+004
6.7917e+004
6.0371e+004
5.2824e+004
4.5278e+004
3.7732e+004
3.0185e+004
2.2639e+004
1.5093e+004
7.5463e+003
0.0000e+000
Z
Y

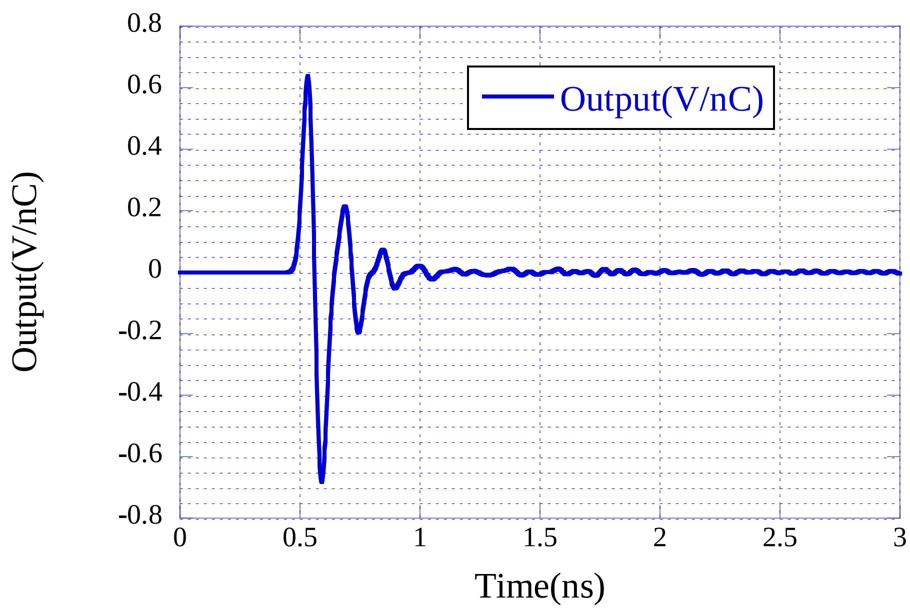
Simulated S-Parameters

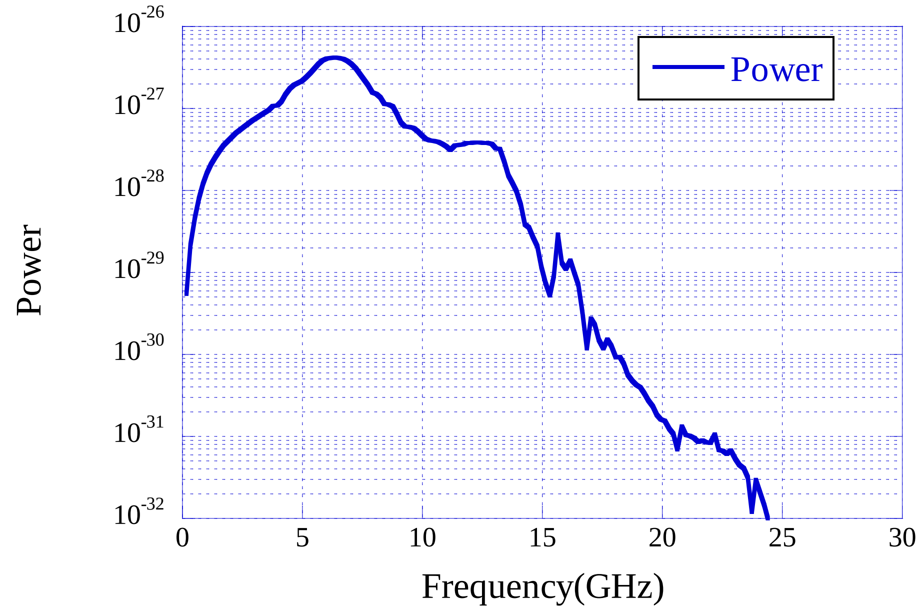


GdfidL model



Simulated Port output

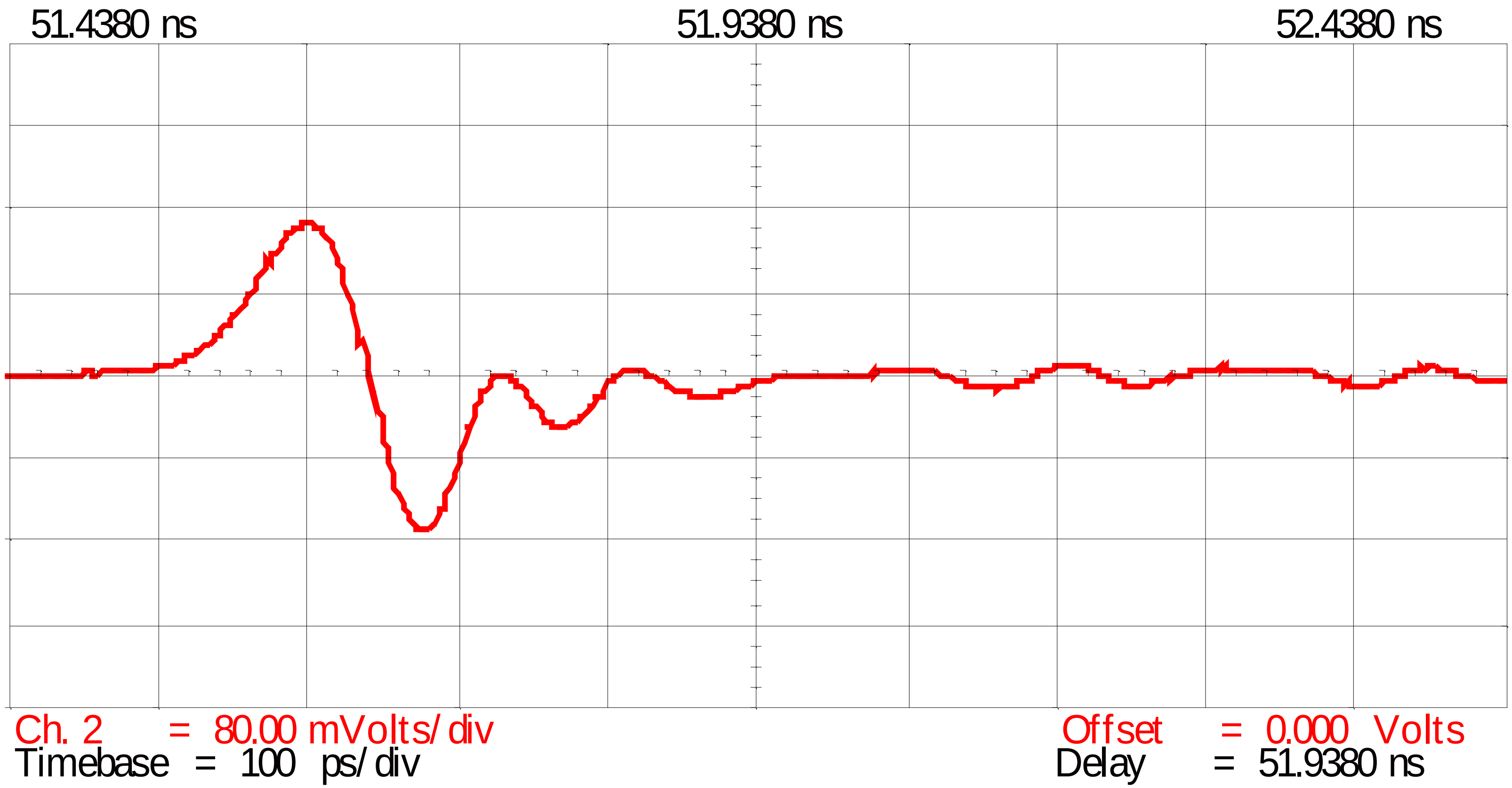




Tips

- **Need to pay attention to the possible trapped modes in the sealing structure, which may damage the seal on high beam current operation.**
  - Use Eigen-mode solver to estimate the frequency of the trapped mode.
  - Fine frequency sweep to find dip structure in S11
  - Coupling to coaxial mode might be difficult.
- **Need to pay attention to the multipactoring around the button gap, especially for high single-bunch current machine.**
- **Longitudinal beam coupling impedance might not be negligible on large circumference, high beam current machine.**

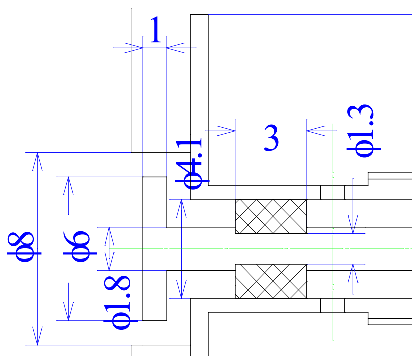
Measured signal (20GHz scope)

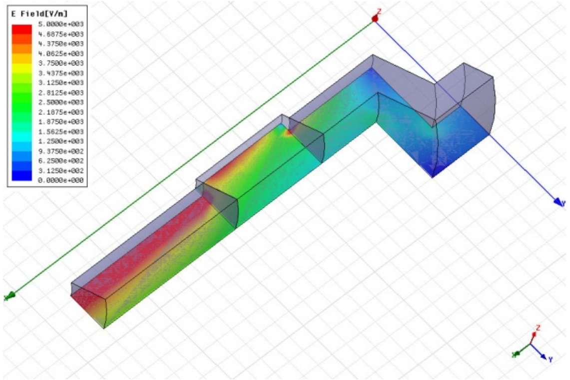


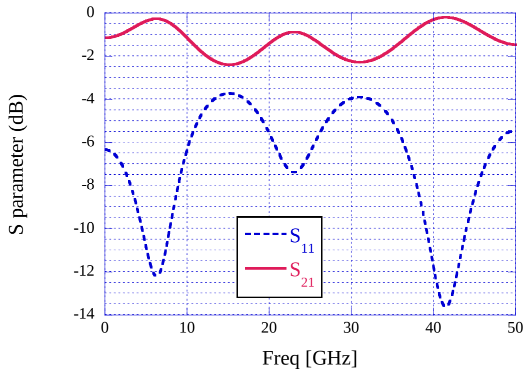
9nC/bunch LER 43dB attenuation, LER upstream

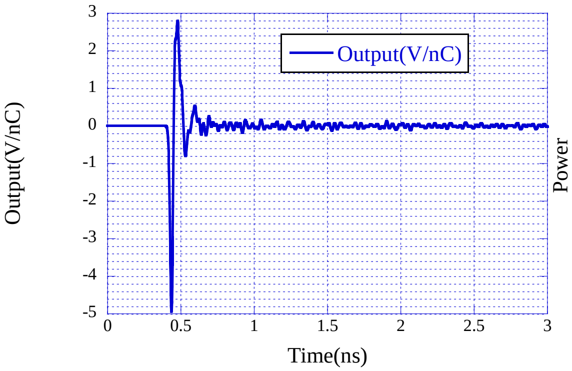
Maximum beam current at KEKB: 2A+1.3A=3.3A with large horizontal offset

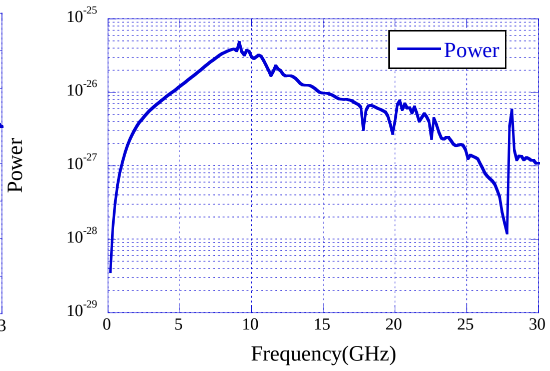
Feedthrough with low εr(~4) sealing



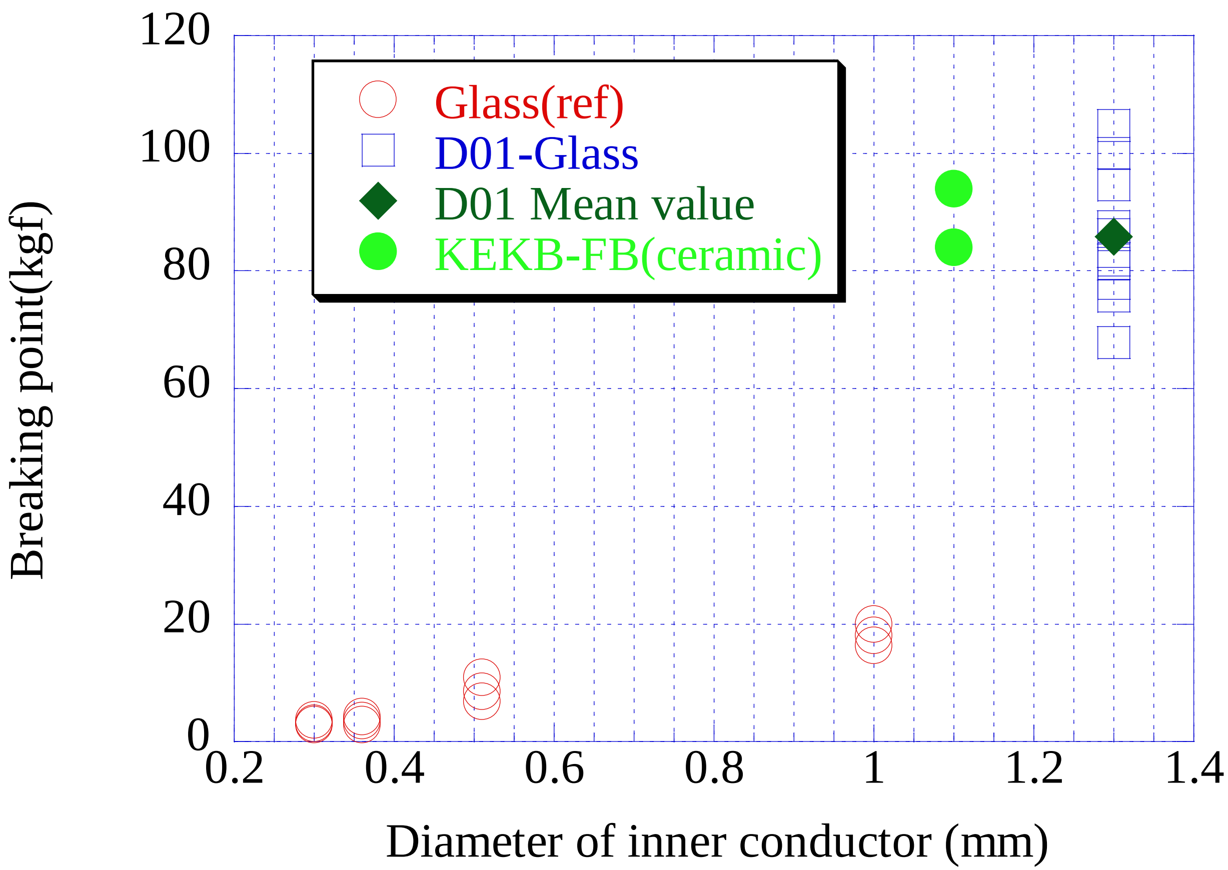




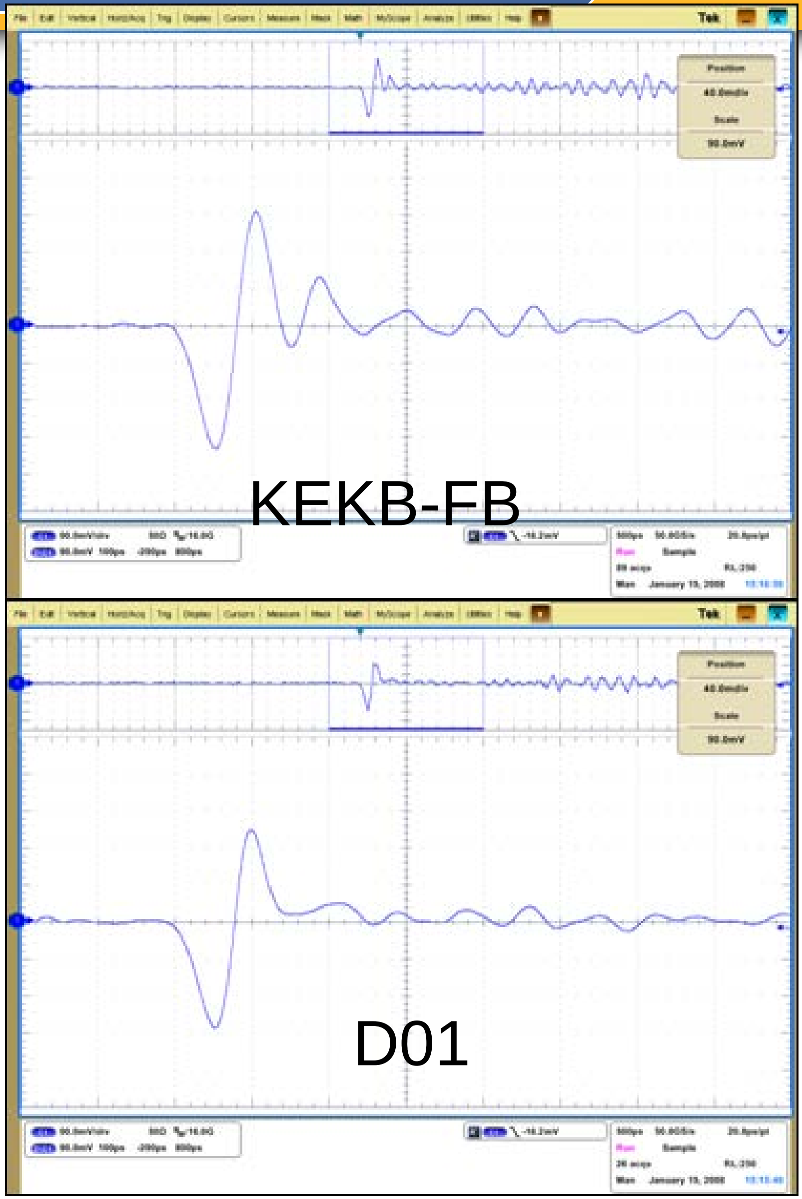




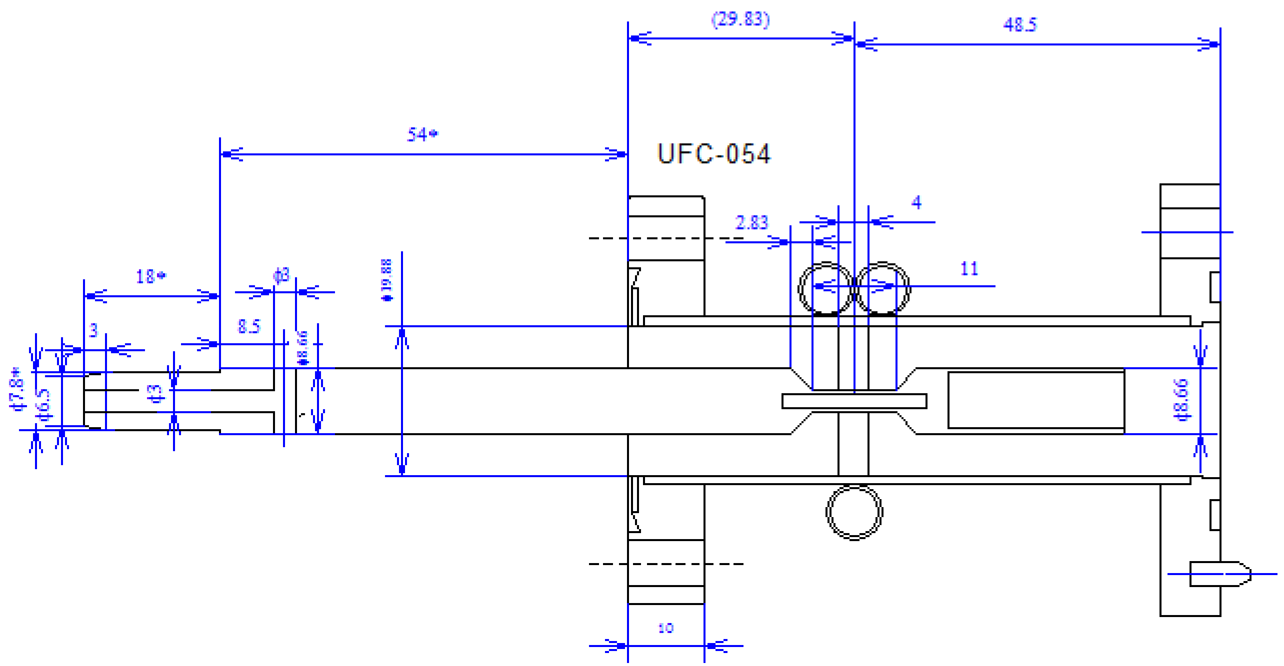
Center pin pulling-out test



Beam test using Linac short pulse



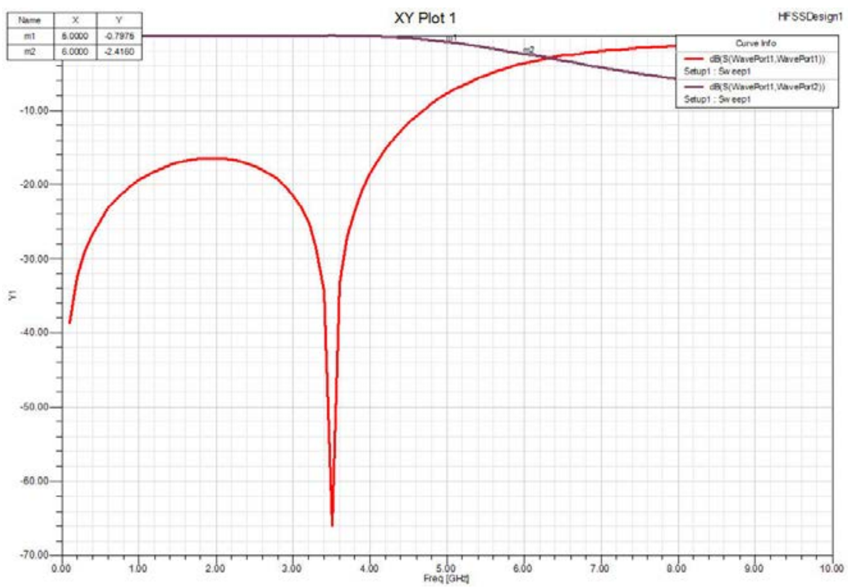
High power feedthrough



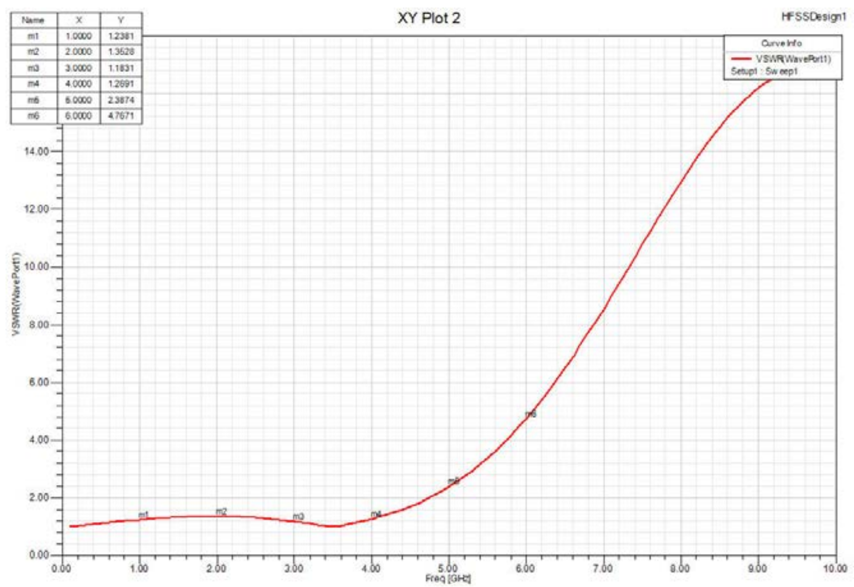
SuperKEKB進行方向キッカー用7/8-EIA FT
*印寸法(3カ所)は試験成績書記載箇所とする。

Simulated S-Parameters

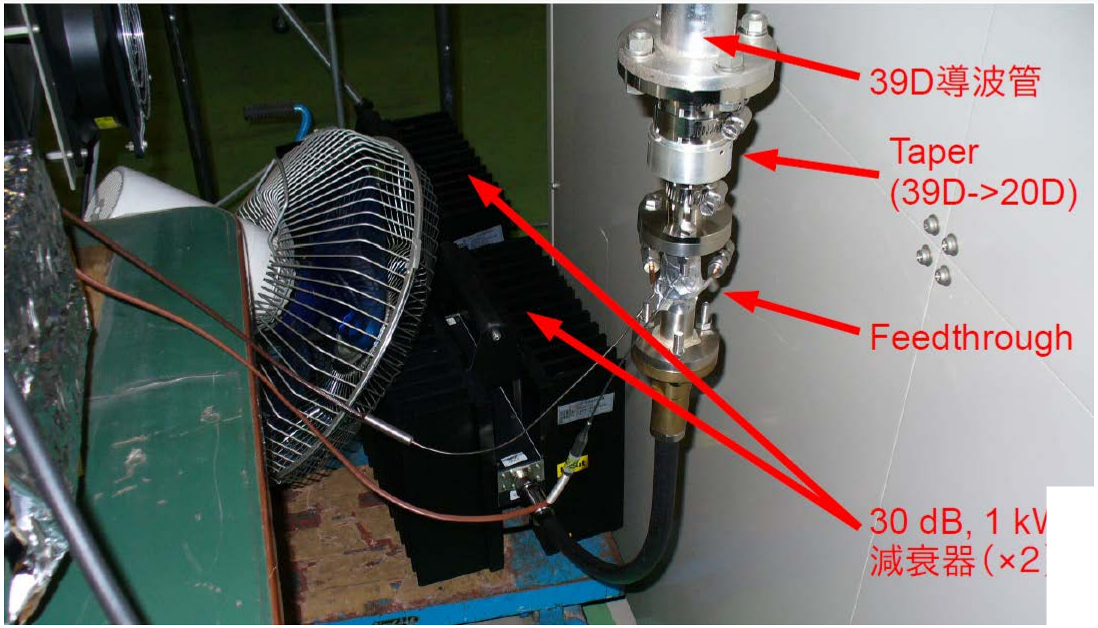
S21 and S11



VSWR(S11)



High power test

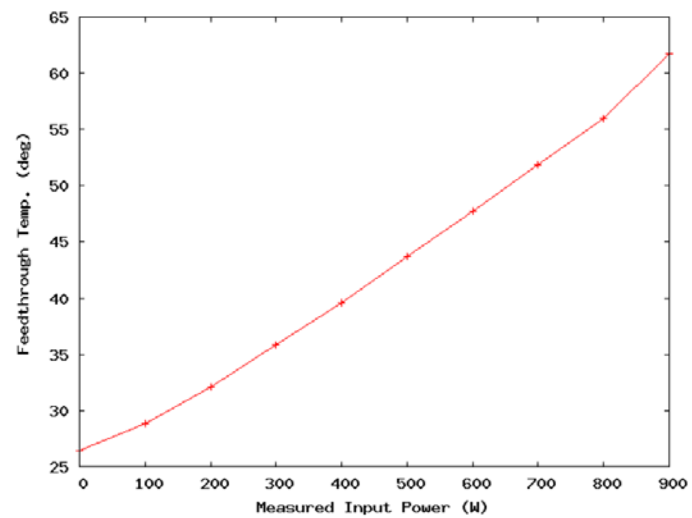


1.3GHz power source

- **Temperature rise :4 deg/100W**

  (without water cooling)

Feedthrough温度対入力パワー



冷却水がなくても900 Wまでは異常無し。

Tips

- **To enhance thermal conductivity between the center conductor and the outer wall, it might be considered to fill BN (ε_R~4) at the air side.**
- **Si_3N_4 has lower ε_R and has better (lower) loss tangent**
  - Expensive
  - Mechanically weaker than alumina-ceramic

Summary

- **Briefly reviewed the transmission-line theory**
  - S-Parameters, SWR, Time-domain response
- **Introduced E-M simulation software**
  - HFSS (Frequency domain)
  - GdfidL (Time domain)
- **Shown several examples**
  - KEKB-FB button electrode
  - SuperKEKB-FB button electrode
  - High power feedthrough for SuperKEKB longitudinal kicker.

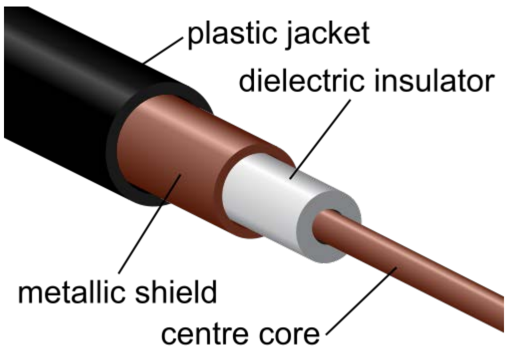
Reference

- "Microwave Engineering Passive Circuits",
  by Peter A. Rizzi, ISBN 0135867029
- "Introduction to Microwave Theory",
  by Harry A. Atwater, ISBN 0898741920
- Ansys HFSS,
  - http://www.ansys.com/Products/Simulation+Technology/Electromagnetics/High-Performance+Electronic+Design/ANSYS+HFSS
- GdfidL, http://www.gdfidl.de/
- Kyocera Corporation
  - http://global.kyocera.com/prdct/fc/product/usage/vacuum/index.html
- Orient Microwave Corp.
  - http://www.orient-microwave.com/english/index.html

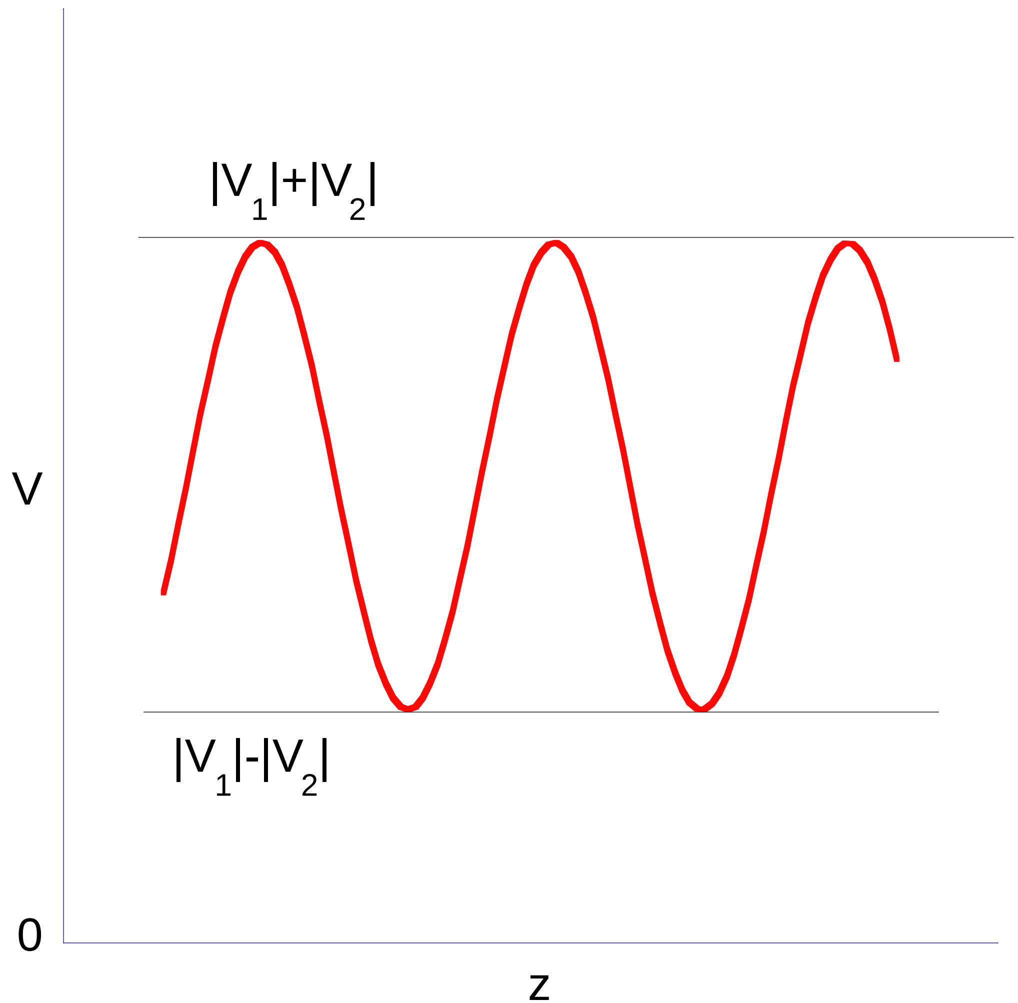
backup

Transmission line

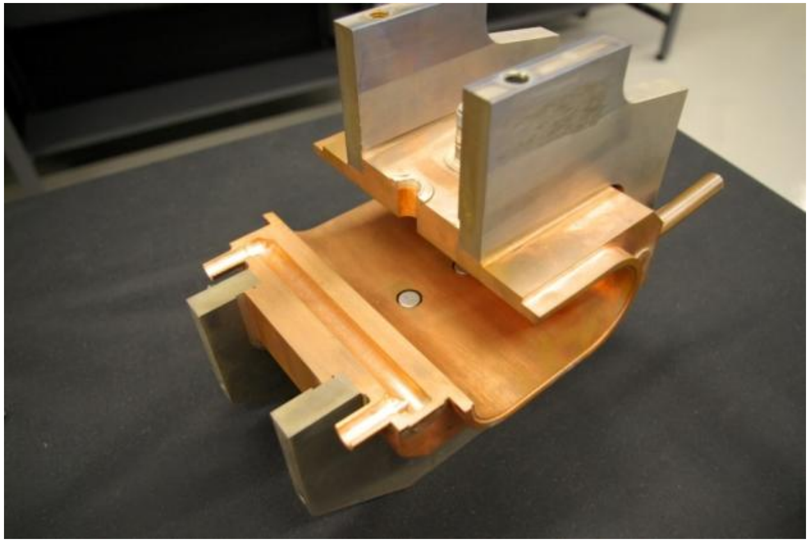
- **Coaxial cable**

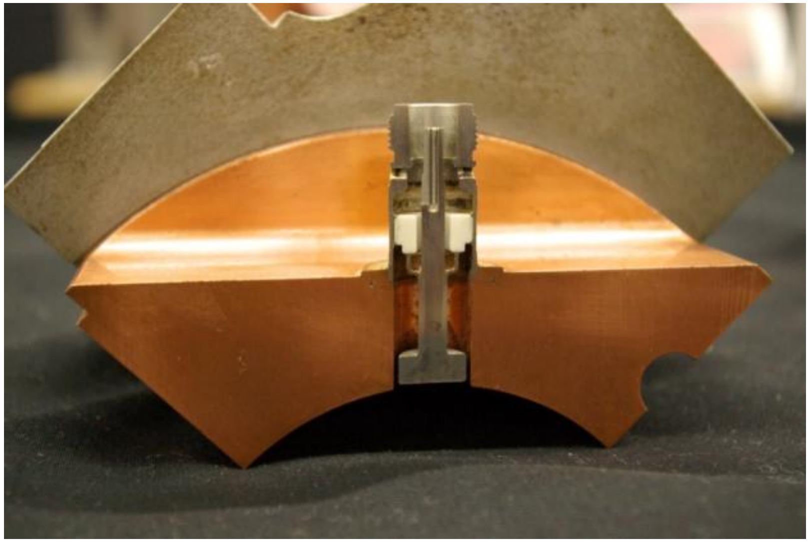


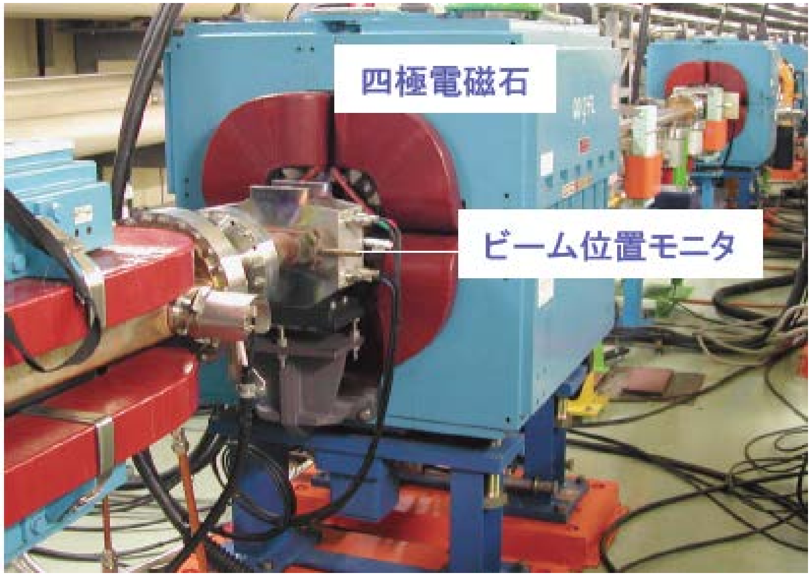
Standing wave



例：ボタン電極型ビーム位置モニタ

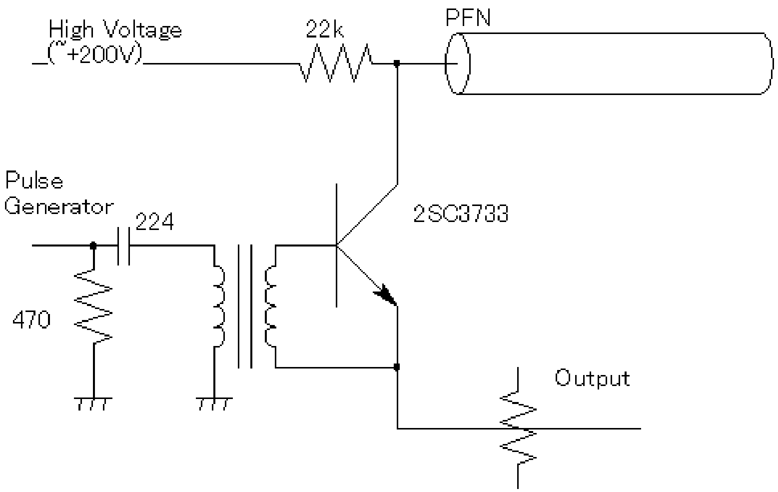


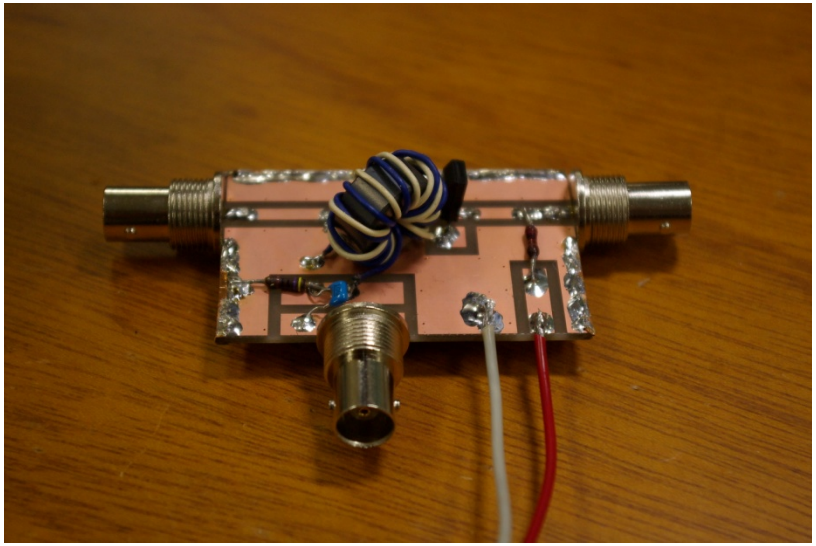




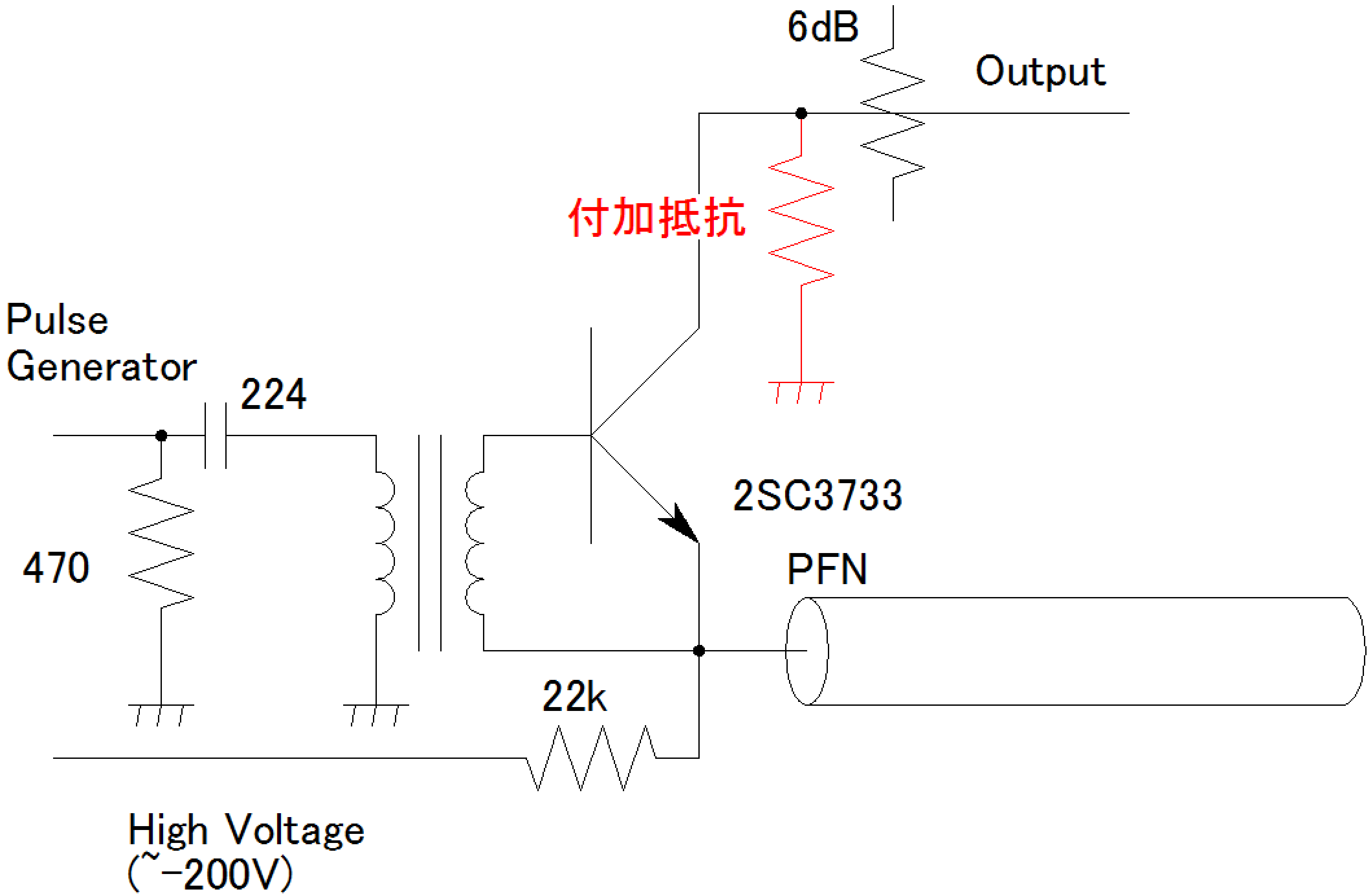
四つの電極に出てきた電荷の差から、バンチの重心位置を求めるためのモニターです。レンズの働きをする四極電磁石に固定してあります。

アバランシェトランジスタパルサー(正極性)

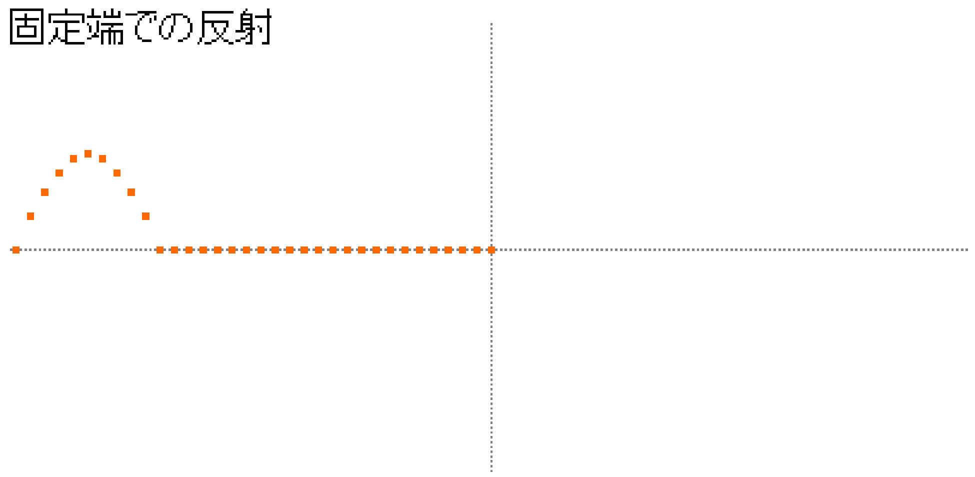


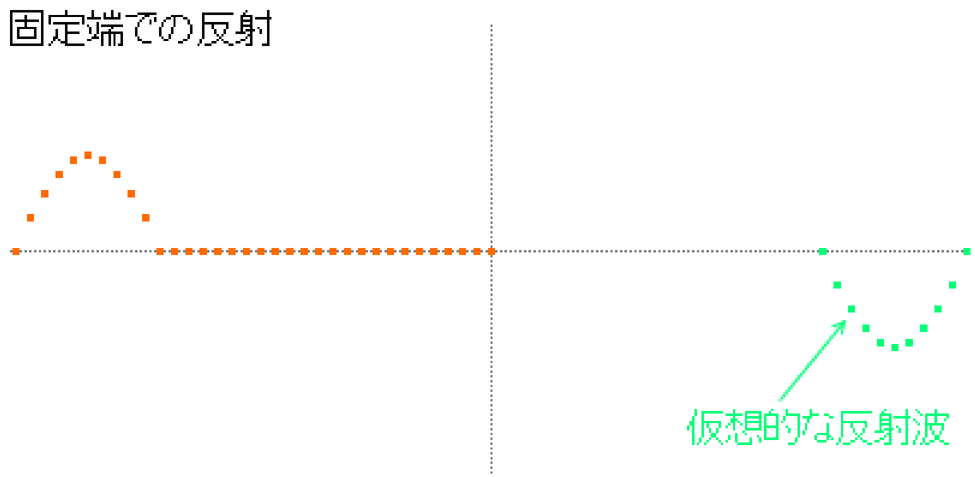


アバランシェパルサー(負極性)



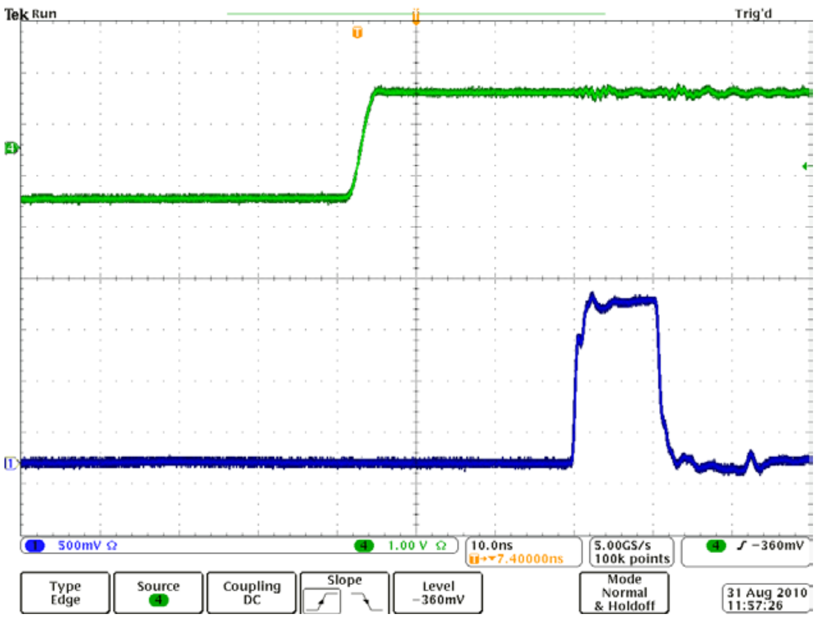
固定端での反射





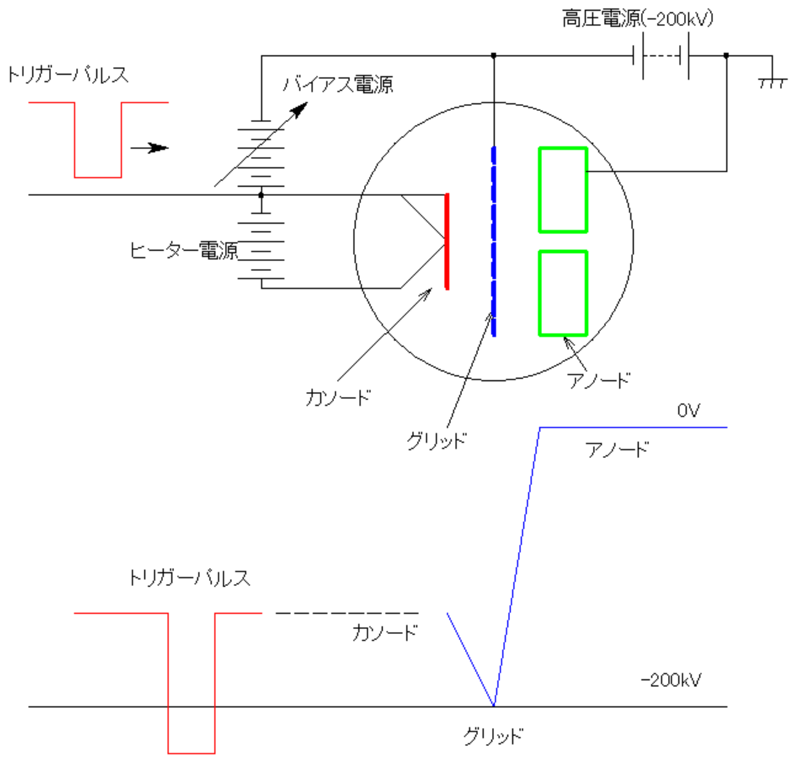
http://www.wakariyasui.sakura.ne.jp/2-1-0-0/2-1-2-4koteitannjiyuutann.html

出力は

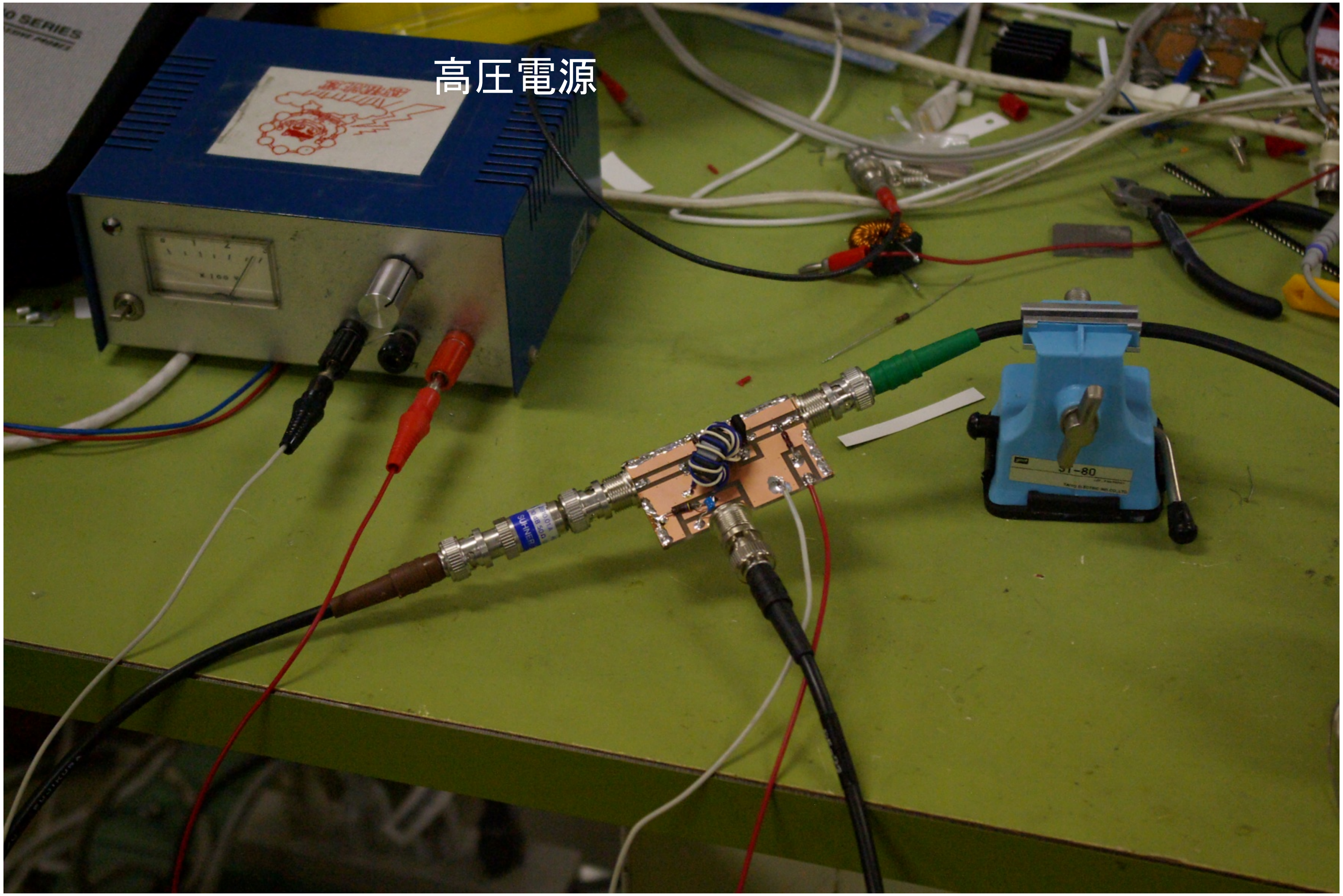


- トリガーが入ってトランジスタがONになり、約10ns後にOFFになっている。
- このとき、PFNには1mの同軸線をつけていた。ここにたまっていた高電圧が抜けて、パルス高が0に戻った。

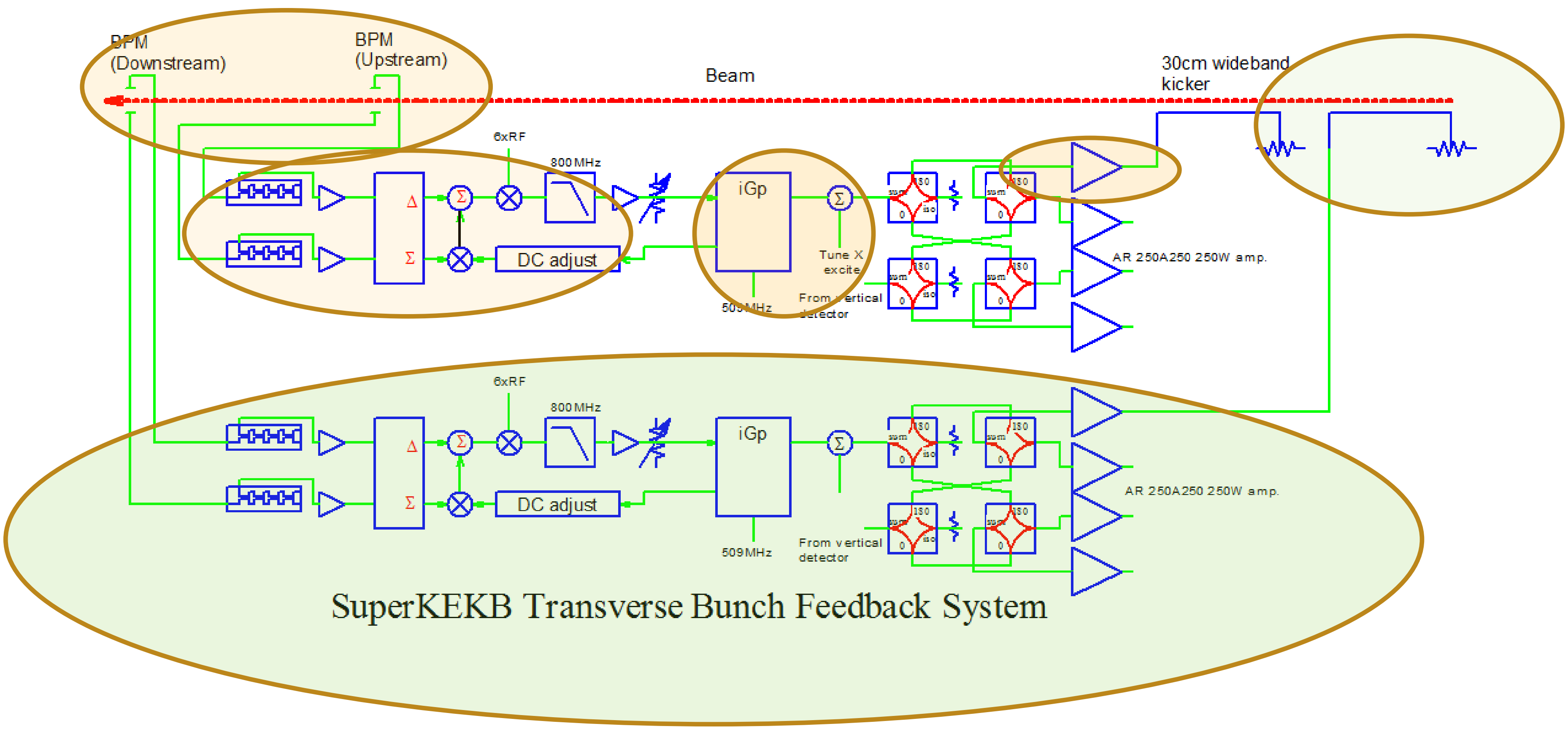
アバランシェパルサーの使用例



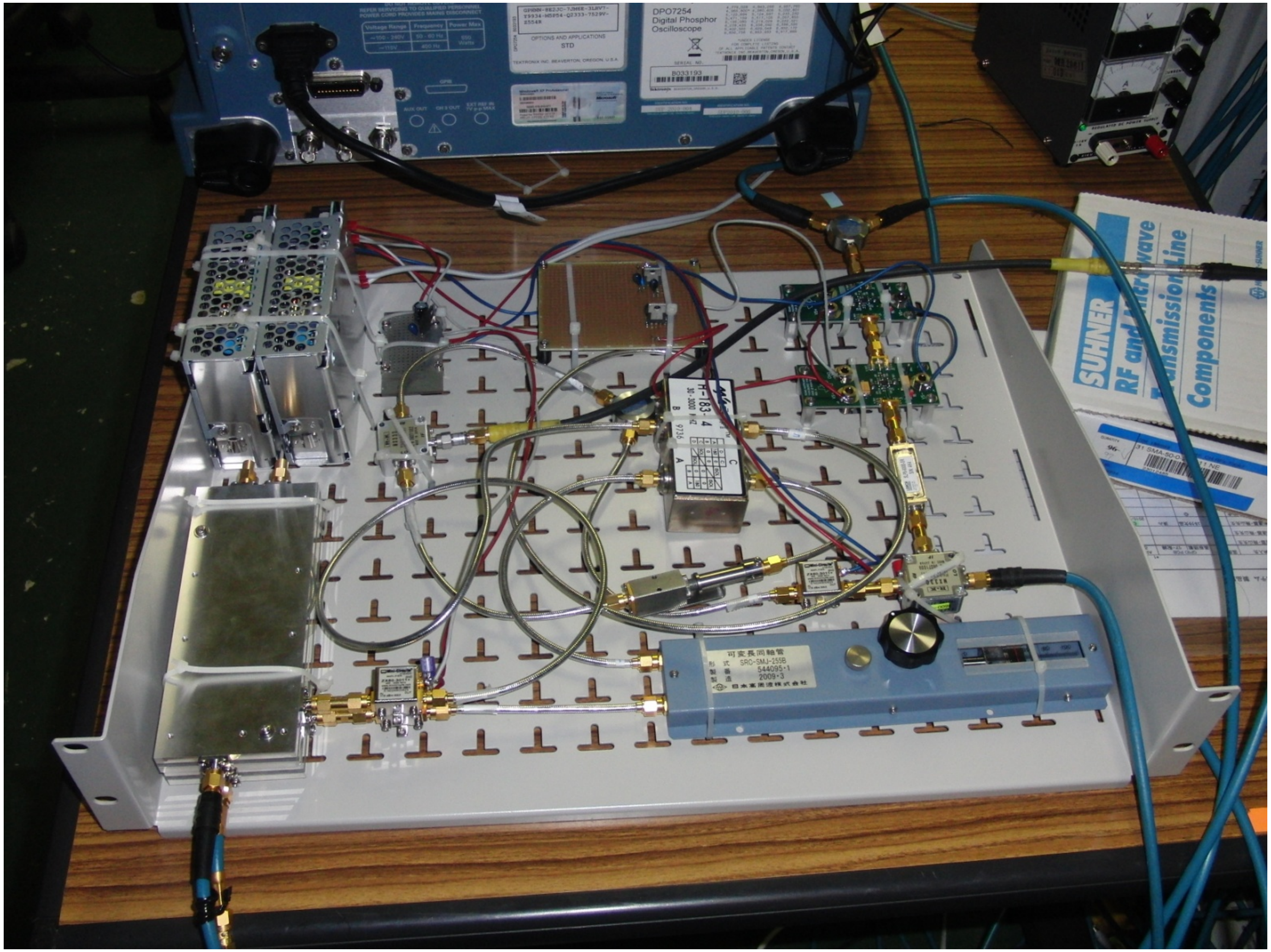
- 線形加速器の熱電子銃から出る電子ビームの長さを非常に狭く(1ns以下とか)したいとき、アバランシェパルサーを使ってビームが出るタイミングを制御します


高圧電源
SERIES
ST-80

SuperKEKB Transverse FB plan



Bunch position detector prototype



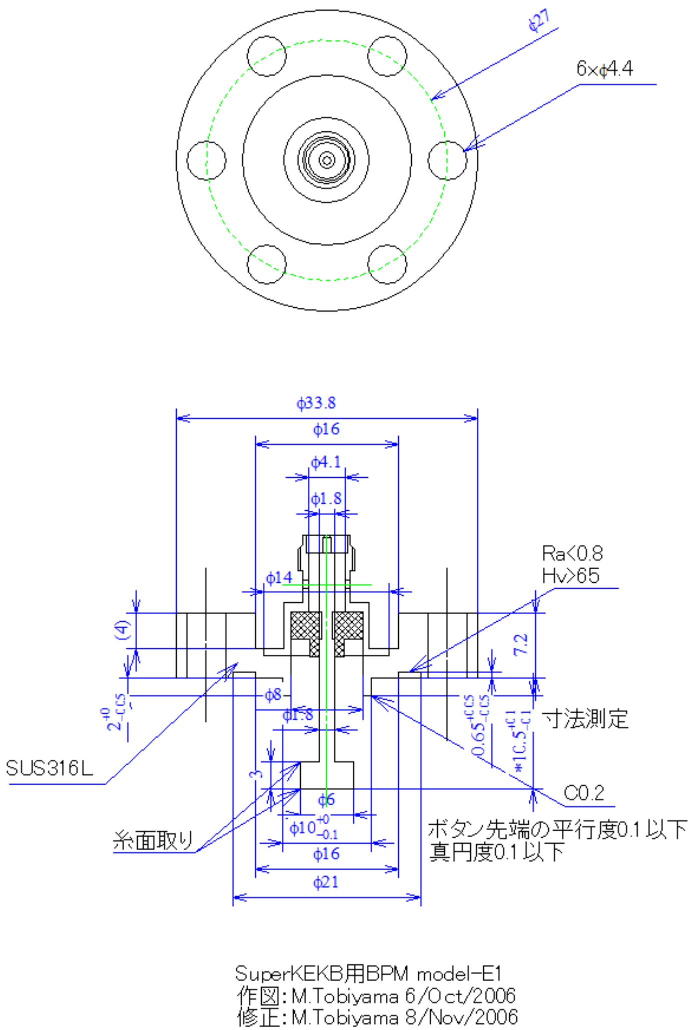
Vacuum chamber

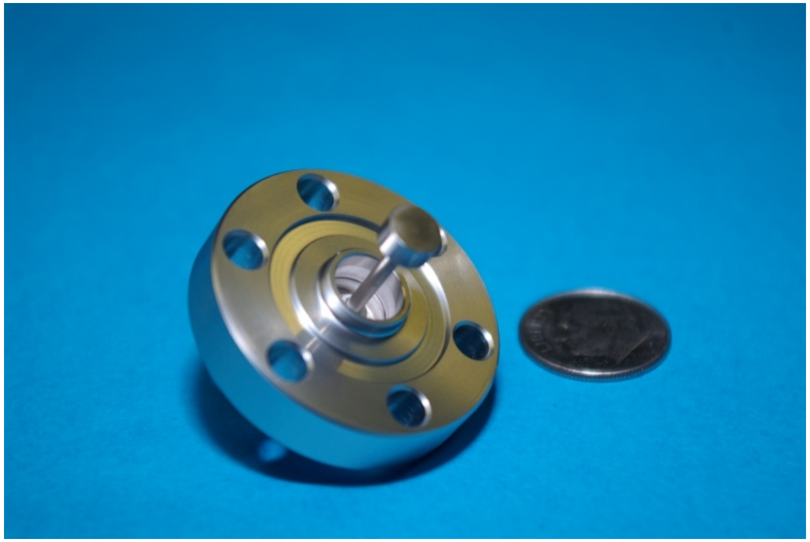
- Aluminum alloy antechamber
- cutoff frequency <1 GHz

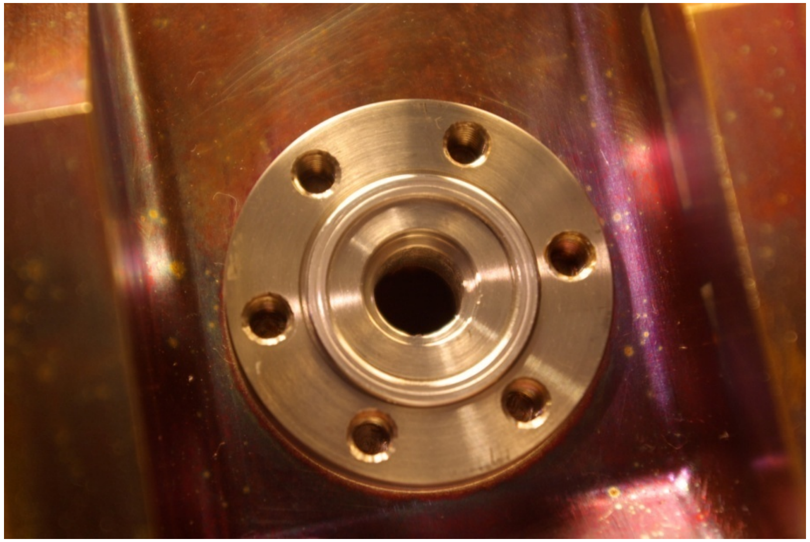
Aluminum-alloy duct

Aluminum-alloy duct

BPM head


φ27
6×φ4.4
φ33.8
φ16
φ4.1
φ1.8
φ14
Ra<0.8
Hv>65
(4)
7.2
φ8
φ1.8
寸法測定
SUS316L
C0.2
φ6
φ16
φ21
糸面取り
ボタン先端の平行度0.1以下
真円度0.1以下
SuperKEKB用BPM model-E1
作図:M.Tobiyama 6/Oct/2006
修正:M.Tobiyama 8/Nov/2006





Impedance/button output simulation