BS PreIsolator Matrices
JGW-T1707205-v4

14 November 2017

1 Coordinates

There are 3 main devices in the PreIsolator (PI), Horizontal Fishing rods (FR), Geophones and PI LVDTs. The PI devices are located 120° apart from each other. The leg #0 of the Inverted Pendulum is in the $-t$ direction and angles are measured anticlockwise from it.

$FR\#0$, $Geo\#0$ and $PI\ LVDT\#0$ are offset by $-30°$, 15° and 30° from Leg #0. Legs #1 and #2 are at 120° and 240°.

In the figure 1 we can see the coordinates L (Longitudinal), T (Transverse) and Y (Yaw). We can also see the position of the devices: $Horizontal\ FR\#0$, $Geo\#0$ and $PI\ LVDT\#0$.

The devices are also located at different distances from the center of the PI, so we define the radius r_F, r_G and r_H as:

- r_F : Radius of the Horizontal FRs.
- r_G : Radius of the Geophones.
- r_H : Radius of the PI LVDTs.

The values of this distances are:

- $r_F = 0.6344[m]$
- $r_G = 0.5915[m]$
- $r_H = 0.594[m]$

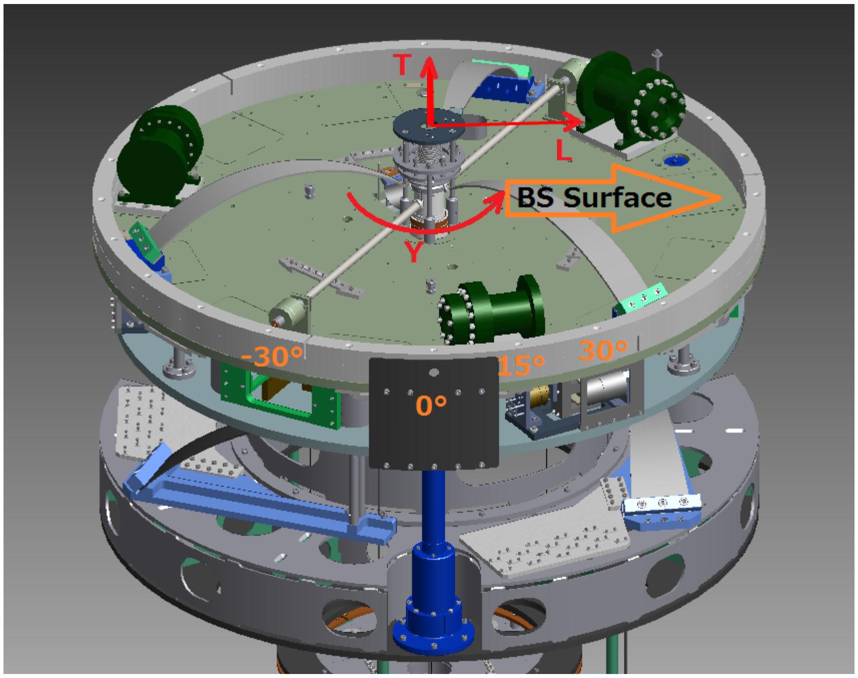


Figure 1: PI Coordinates

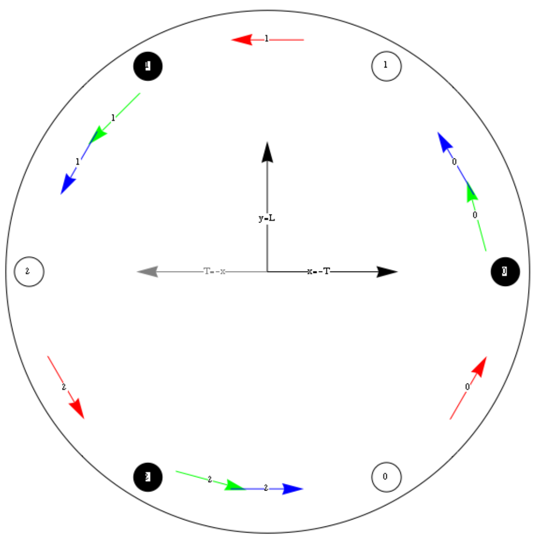
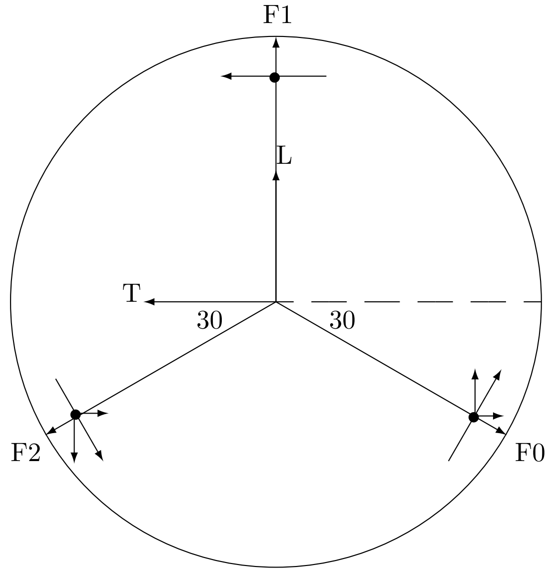


Figure 2: BS PI Matrix calculation geometry

2 Horizontal FR Matrix



F0: PI Horizontal FR#0
F1: PI Horizontal FR#1
F2: PI Horizontal FR#2

- The equations for the Horizontal FRs are:

$$\begin{aligned} F_0 &= l \cdot \cos(30) - t \cdot \cos(60) + r_F \cdot y \\ F_1 &= 0 + t + r_F \cdot y \\ F_2 &= -l \cdot \cos(30) - t \cdot \cos(60) + r_F \cdot y \end{aligned} \tag{1}$$

So the corresponding matrix for the Horizontal FRs is:

$$\begin{pmatrix} F_0 \\ F_1 \\ F_2 \end{pmatrix} = \begin{pmatrix} \cos(30) & -\cos(60) & r_F \\ 0 & 1 & r_F \\ -\cos(30) & -\cos(60) & r_F \end{pmatrix} \cdot \begin{pmatrix} l \\ t \\ y \end{pmatrix} \tag{2}$$

$$\begin{pmatrix} F_0 \\ F_1 \\ F_2 \end{pmatrix} = \begin{pmatrix} \frac{\sqrt{3}}{2} & \frac{-1}{2} & 0.6344 \\ 0 & 1 & 0.6344 \\ \frac{-\sqrt{3}}{2} & \frac{-1}{2} & 0.6344 \end{pmatrix} \cdot \begin{pmatrix} l \\ t \\ y \end{pmatrix} \tag{3}$$

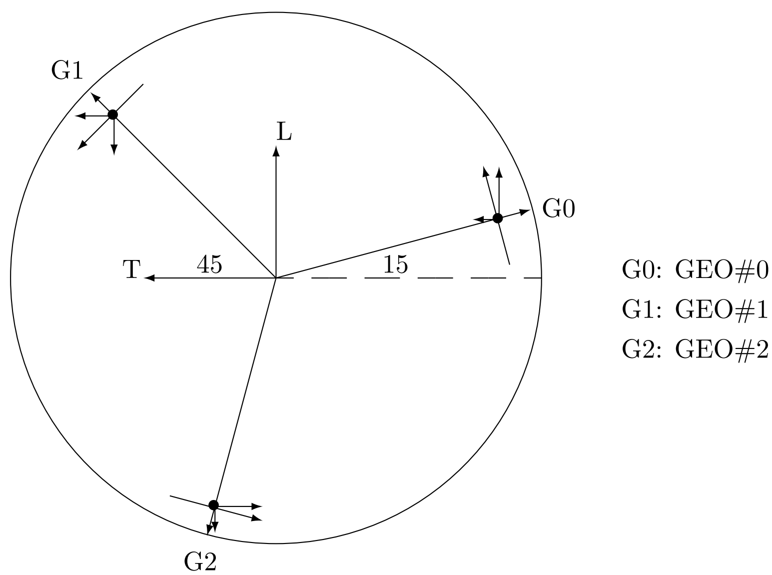
$$Q = \begin{pmatrix} 0.86603 & -0.5 & 0.6344 \\ 0 & 1 & 0.6344 \\ 0.86603 & -0.5 & 0.6344 \end{pmatrix} \tag{4}$$

We need to write a Python script to take DC force/torque requests in LTY coordinates, multiply by this matrix and output stepper motor movements in steps.

And the inverse of the matrix Q to convert the signals from the virtual sensors into the coordinates (L,T,Y) is:

$$Q^{-1} = \begin{pmatrix} \frac{\sqrt{3}}{3} & 0 & \frac{-\sqrt{3}}{3} \\ \frac{-1}{3} & \frac{2}{3} & \frac{-1}{3} \\ \frac{1}{3 \cdot r_F} & \frac{1}{3 \cdot r_F} & \frac{1}{3 \cdot r_F} \end{pmatrix} = \begin{pmatrix} 0.57735 & 0 & -0.57735 \\ -0.33333 & 0.66667 & -0.33333 \\ 0.52543 & 0.52543 & 0.52543 \end{pmatrix} \tag{5}$$

3 Geophones Matrix



- The equations for the Geophones are:

$$\begin{aligned} G_0 &= l \cdot \cos(15) + t \cdot \cos(75) + r_G \cdot y \\ G_1 &= -l \cdot \cos(45) + t \cdot \cos(45) + r_G \cdot y \\ G_2 &= -l \cdot \cos(75) - t \cdot \cos(15) + r_G \cdot y \end{aligned} \tag{6}$$

So the corresponding matrix for the Geophones is:

$$\begin{pmatrix} G_0 \\ G_1 \\ G_2 \end{pmatrix} = \begin{pmatrix} \cos(15) & \cos(75) & r_G \\ -\cos(45) & \cos(45) & r_G \\ -\cos(75) & -\cos(15) & r_G \end{pmatrix} \cdot \begin{pmatrix} l \\ t \\ y \end{pmatrix} \tag{7}$$

$$\begin{pmatrix} G_0 \\ G_1 \\ G_2 \end{pmatrix} = \begin{pmatrix} \frac{(\sqrt{3}+1)}{2\sqrt{2}} & \frac{(\sqrt{3}-1)}{2\sqrt{2}} & 0.5915 \\ -\frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} & 0.5915 \\ \frac{-(\sqrt{3}-1)}{2\sqrt{2}} & \frac{-(\sqrt{3}+1)}{2\sqrt{2}} & 0.5915 \end{pmatrix} \cdot \begin{pmatrix} l \\ t \\ y \end{pmatrix} \tag{8}$$

$$R = \begin{pmatrix} 0.96593 & 0.25882 & 0.5915 \\ -0.70711 & 0.70711 & 0.5915 \\ -0.25882 & -0.96593 & 0.5915 \end{pmatrix} \tag{9}$$

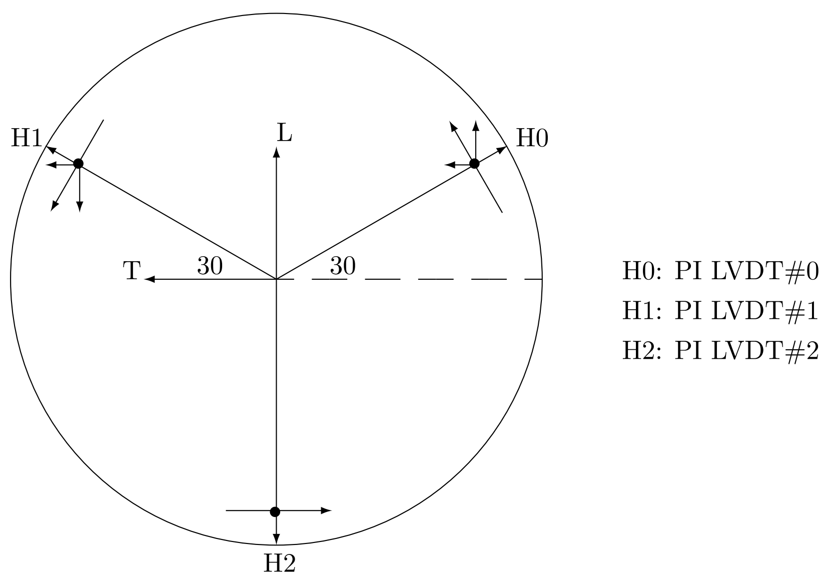
We would type these numbers into $EUL2ACC$ if it existed, which it doesn't because Geophones don't have actuation.

And the inverse of the matrix R to convert the signals from the virtual sensors into the coordinates (L,T,Y) is:

$$R^{-1} = \begin{pmatrix} \frac{(\sqrt{3}+1)\sqrt{2}}{6} & -\frac{\sqrt{2}}{3} & \frac{-(\sqrt{3}-1)\sqrt{2}}{6} \\ \frac{(\sqrt{3}-1)\sqrt{2}}{6} & \frac{\sqrt{2}}{3} & \frac{-(\sqrt{3}+1)\sqrt{2}}{6} \\ \frac{1}{3\cdot r_G} & \frac{1}{3\cdot r_G} & \frac{1}{3\cdot r_G} \end{pmatrix} = \begin{pmatrix} 0.64395 & -0.47140 & -0.17255 \\ 0.17255 & 0.47140 & -0.64395 \\ 0.56354 & 0.56354 & 0.56354 \end{pmatrix} \tag{10}$$

Then we need to type this numbers into $ACC2EUL$ matrix of the real time model.

4 PI LVDTs Matrix



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The equations for the PI LVDTs are:

$$\begin{aligned} H_0 &= l \cdot \cos(30) + t \cdot \cos(60) + r_H \cdot y \\ H_1 &= -l \cdot \cos(30) + t \cdot \cos(60) + r_H \cdot y \\ H_2 &= 0 - t + r_H \cdot y \end{aligned} \tag{11}$$

So the corresponding matrix for the PI LVDTs is:

$$\begin{pmatrix} H_0 \\ H_1 \\ H_2 \end{pmatrix} = \begin{pmatrix} \cos(30) & \cos(60) & r_H \\ -\cos(30) & \cos(60) & r_H \\ 0 & -1 & r_H \end{pmatrix} \cdot \begin{pmatrix} l \\ t \\ y \end{pmatrix} \tag{12}$$

$$\begin{pmatrix} H_0 \\ H_1 \\ H_2 \end{pmatrix} = \begin{pmatrix} \frac{\sqrt{3}}{2} & \frac{1}{2} & 0.594 \\ \frac{-\sqrt{3}}{2} & \frac{1}{2} & 0.594 \\ 0 & -1 & 0.594 \end{pmatrix} \cdot \begin{pmatrix} l \\ t \\ y \end{pmatrix} \tag{13}$$

$$S = \begin{pmatrix} 0.86603 & 0.5 & 0.594 \\ -0.86603 & 0.5 & 0.594 \\ 0 & -1 & 0.594 \end{pmatrix} \tag{14}$$

We need to type this numbers into $EUL2COIL$ matrix of the real time model. And this is because the actuation is only produced by the LVDTs.

And the inverse of the matrix S to convert the signals from the sensors into the coordinates (L,T,Y) is:

$$S^{-1} = \begin{pmatrix} \frac{\sqrt{3}}{3} & \frac{-\sqrt{3}}{3} & 0 \\ \frac{1}{3} & \frac{1}{3} & \frac{-2}{3} \\ \frac{1}{3 \cdot r_H} & \frac{1}{3 \cdot r_H} & \frac{1}{3 \cdot r_H} \end{pmatrix} = \begin{pmatrix} 0.57735 & -0.57735 & 0 \\ 0.33333 & 0.33333 & -0.66667 \\ 0.56117 & 0.56117 & 0.56117 \end{pmatrix} \tag{15}$$

And then we need to type this numbers into $LVDT2EUL$ matrix of the real time model.