Corollary

Discrete time State-Space equations

$$x[n+1] = Ax[n] + Bu[n]$$

$$y[n] = Cx[n]$$

$$T_s = 100\ [\mu s]$$

Continous time State-Space equations

$$\dot{x}(t) = Ax(t) + Bu(t)$$

$$y(t) = Cx(t)$$

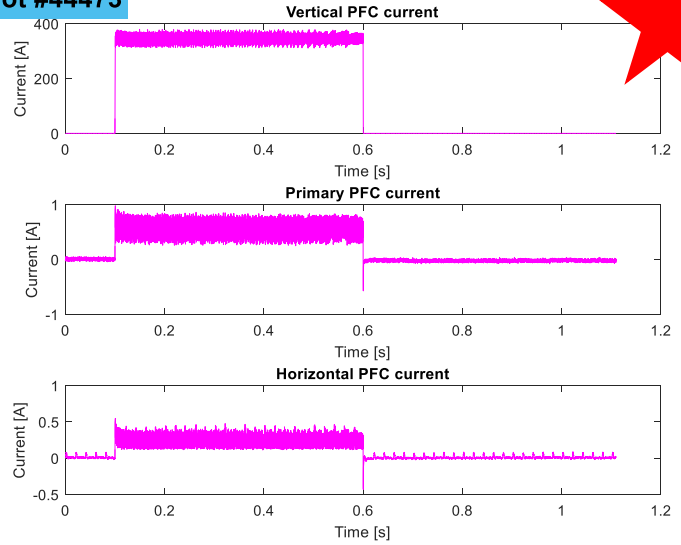
Discrete equations for programming in the GAM

A linear discrete-time system described by the state equation $x(k+1) = A\,x(k) + b\,u(k)$ is asymptotically stable if and only if all eigenvalues have magnitude smaller than one.

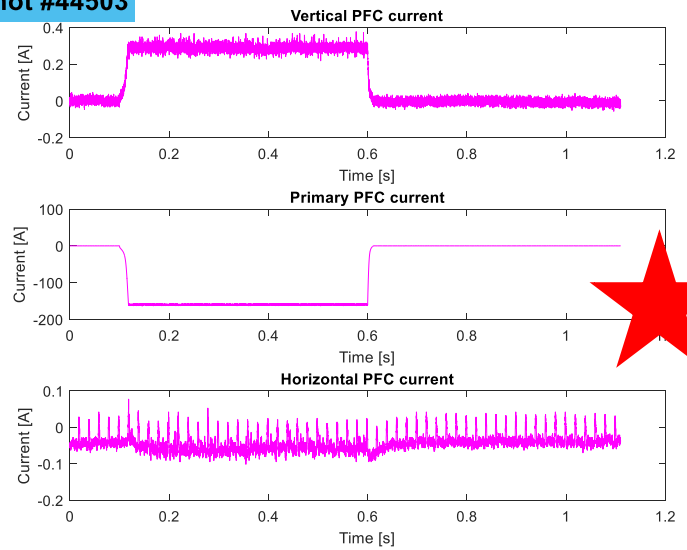
```
time_sec=1e-6*data.time(11:end);
y=lsim(ss1,input_vector,time_sec');
```

Modelling shots

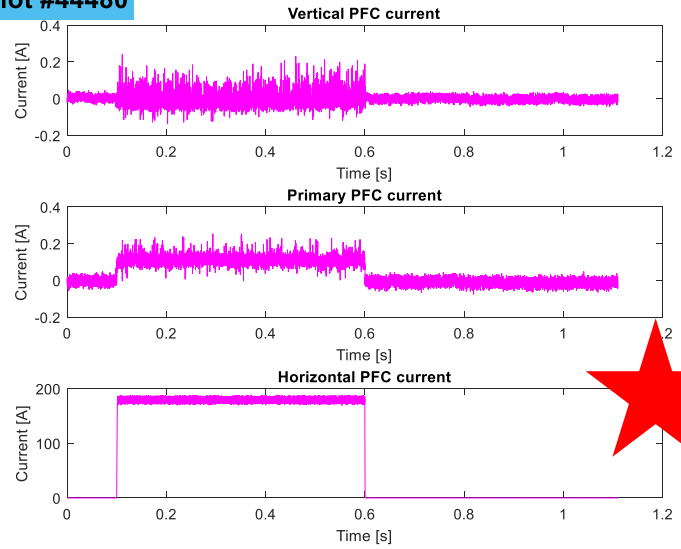
Shot #44473



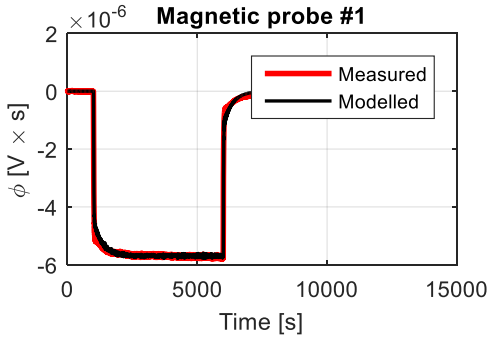
Shot #44503

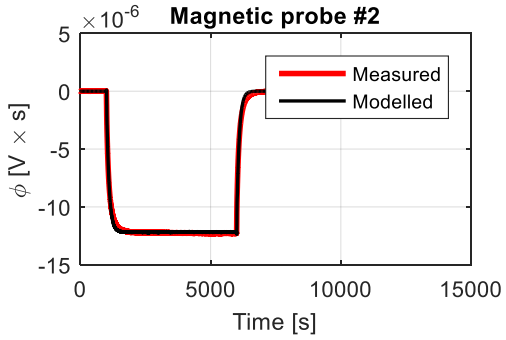


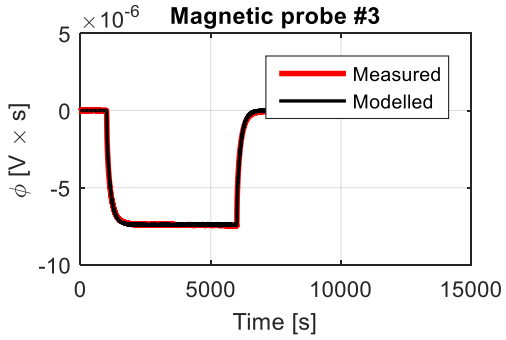
Shot #44480

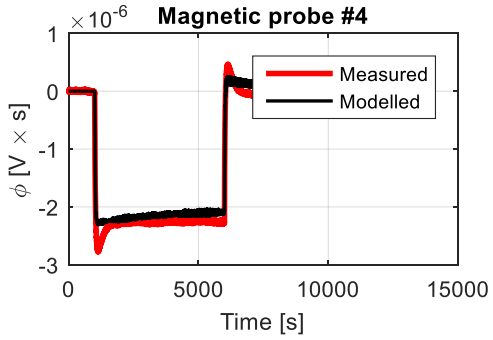


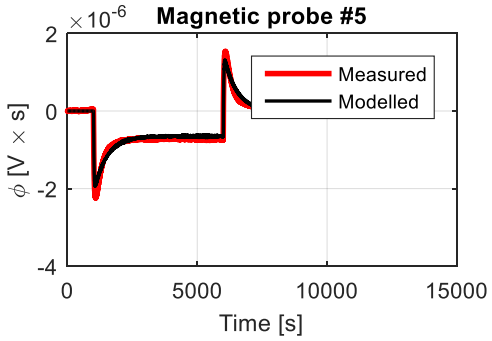
Shot #44480

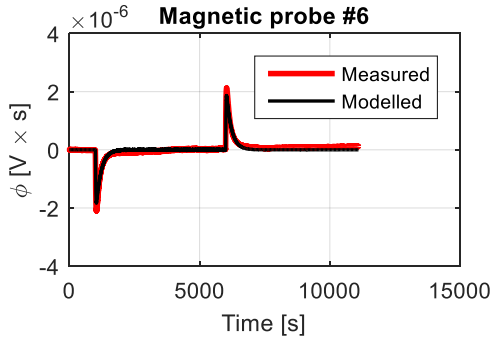

Magnetic probe #1
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]

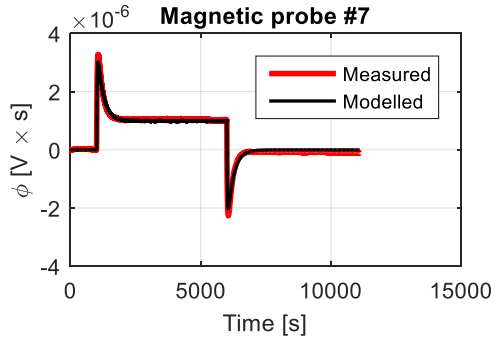

Magnetic probe #2
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]

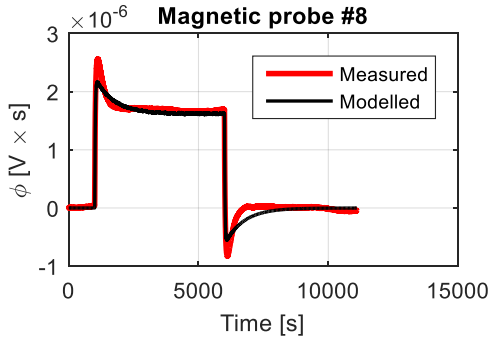

Magnetic probe #3
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]

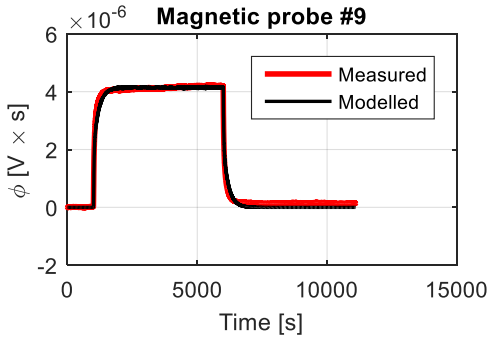

Magnetic probe #4
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]

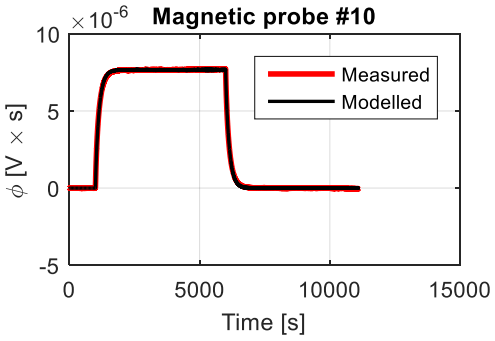

Magnetic probe #5
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]

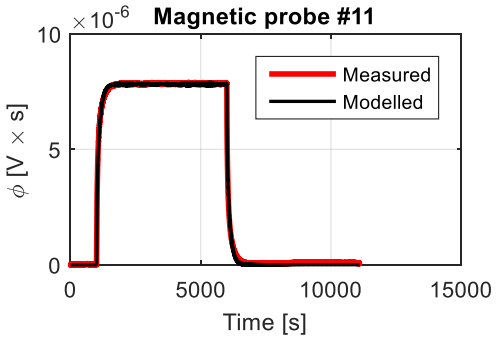

Magnetic probe #6
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]

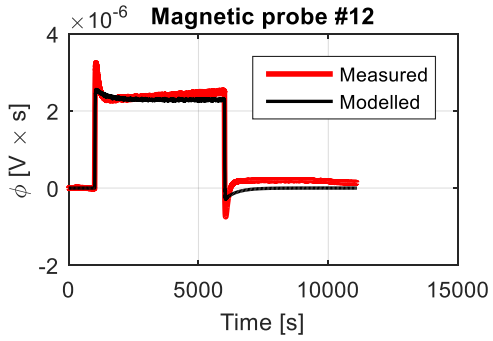

Magnetic probe #7
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]


Magnetic probe #8
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]


Magnetic probe #9
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]


Magnetic probe #10
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]


Magnetic probe #11
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]


Magnetic probe #12
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]

Shot #44480

$$x[n+1] = Ax[n] + Bu_{horizontal}[n]$$
$$y_{horizontal}[n] = Cx[n]$$

	mirnv1	mirnv2	mirnv3	mirnv4
x_0	$\begin{bmatrix} -0.0003 \\ -0.0013 \\ -0.0116 \\ -0.0028 \end{bmatrix}$	$\begin{bmatrix} 0 \\ 0.0043 \\ -0.0005 \\ 0.0028 \end{bmatrix}$	$\begin{bmatrix} -0.0001 \\ -0.0108 \\ -0.0015 \\ 0.0077 \end{bmatrix}$	$\begin{bmatrix} 0.0015 \\ 0.0111 \\ -0.0034 \\ -0.0042 \end{bmatrix}$
A	$\begin{bmatrix} 0.9721 & -0.0326 & -0.0061 & 0.0111 \\ -0.0652 & 0.9102 & -0.0437 & 0.0786 \\ -0.0021 & -0.0113 & 0.8091 & 0.5950 \\ -0.0251 & -0.0883 & -0.5616 & 0.7994 \end{bmatrix}$	$\begin{bmatrix} 0.9890 & -0.0052 & -0.0037 & 0.0024 \\ -0.0668 & 0.7655 & 0.4834 & 0.0621 \\ 0.0444 & 0.1091 & 0.5870 & -1.0826 \\ 0.0347 & 0.2852 & -0.3127 & -0.2216 \end{bmatrix}$	$\begin{bmatrix} 0.9911 & -0.0040 & -0.0030 & -0.0025 \\ -0.0326 & 0.8415 & -0.4706 & -0.0508 \\ 0.0145 & 0.4454 & 0.8093 & -0.3695 \\ -0.0338 & 0.1428 & 0.3406 & 0.8775 \end{bmatrix}$	$\begin{bmatrix} 0.9759 & -0.0401 & -0.0430 & -0.0229 \\ -0.0048 & 0.8243 & -0.5626 & 0.0195 \\ 0.0596 & 0.5560 & 0.8088 & -0.1765 \\ -0.0188 & 0.0708 & 0.1653 & 0.9535 \end{bmatrix}$
B	$\begin{bmatrix} -0.0001 \\ 0 \\ 0.0019 \\ -0.0003 \end{bmatrix}$	$\begin{bmatrix} 0 \\ 0.0002 \\ 0.0038 \\ 0.0040 \end{bmatrix}$	$1.0e-03 * \begin{bmatrix} 0.0082 \\ 0.4674 \\ 0.4001 \\ -0.5271 \end{bmatrix}$	$1.0e-03 * \begin{bmatrix} -0.0416 \\ 0.2097 \\ 0.1572 \\ -0.1167 \end{bmatrix}$
C	*1.0e-04* *[0.2379 0.0087 0.0012 0.0013]	$1.0e-03 * [0.1081 \quad 0.0001 \quad 0.0001 \quad 0.0001]$	$1.0e-04 * [0.7142 \quad 0.0021 \quad -0.0008 \quad -0.0001]$	$1.0e-04 * [0.1182 \quad 0.0030 \quad -0.0017 \quad 0.0004]$

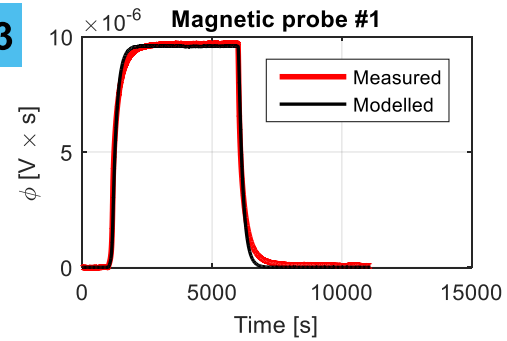
$$x[n+1] = Ax[n] + Bu_{horizontal}[n]$$
$$y_{horizontal}[n] = Cx[n]$$

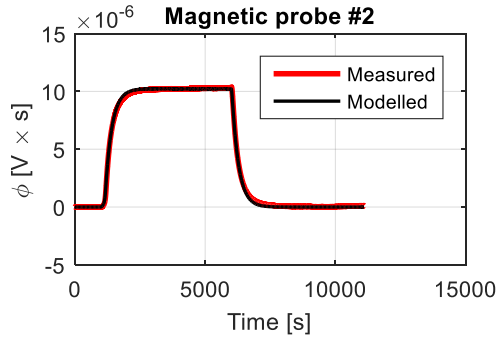
	mirnv5	mirnv6	mirnv7	mirnv8
x_0	$\begin{bmatrix} 0.0002 \\ 0.0034 \\ 0.0121 \\ 0.0041 \end{bmatrix}$	$\begin{bmatrix} -0.0002 \\ -0.0026 \\ -0.0123 \\ 0.0037 \end{bmatrix}$	$\begin{bmatrix} -0.0001 \\ -0.0004 \\ 0.0002 \\ 0.0014 \end{bmatrix}$	$\begin{bmatrix} -0.0002 \\ -0.0019 \\ -0.0135 \\ -0.0044 \end{bmatrix}$
A	$\begin{bmatrix} 0.9998 & -0.0145 & -0.0039 & 0.0087 \\ 0.0073 & 0.9215 & -0.1037 & 0.1497 \\ -0.0006 & 0.0304 & 0.8199 & 0.5662 \\ -0.0114 & -0.1889 & -0.5493 & 0.8112 \end{bmatrix}$	$\begin{bmatrix} 0.9994 & -0.0167 & -0.0031 & -0.0068 \\ 0.0251 & 0.8960 & -0.0582 & -0.0925 \\ -0.0026 & 0.0015 & 0.8130 & -0.5863 \\ 0.0063 & 0.1171 & 0.5652 & 0.8039 \end{bmatrix}$	$\begin{bmatrix} 0.9996 & -0.0208 & 0.0112 & 0.0027 \\ 0.0126 & 0.9118 & 0.0834 & 0.0073 \\ 0.0131 & 0.2135 & 0.0647 & -0.7607 \\ 0.0005 & -0.0272 & -0.2133 & -0.0849 \end{bmatrix}$	$\begin{bmatrix} 0.9943 & -0.0259 & -0.0041 & 0.0083 \\ -0.0087 & 0.9473 & -0.0247 & 0.0483 \\ 0.0049 & -0.0160 & 0.8105 & 0.5887 \\ -0.0175 & -0.0719 & -0.5718 & 0.8019 \end{bmatrix}$
B	$1.0e-03 * \begin{bmatrix} -0.0151 \\ 0.0303 \\ 0.5044 \\ -0.1020 \end{bmatrix}$	$1.0e-03 * \begin{bmatrix} -0.0244 \\ -0.0719 \\ 0.8074 \\ 0.1968 \end{bmatrix}$	$\begin{bmatrix} 0.0001 \\ 0.0003 \\ -0.0044 \\ -0.0046 \end{bmatrix}$	$1.0e-03 * \begin{bmatrix} 0.0293 \\ 0.0212 \\ -0.6610 \\ 0.2805 \end{bmatrix}$
C	*1.0e-04* *[0.3215 0.0021 0.0007 0.0013]	*1.0e-04* *[0.3228 0.0015 0.0005 −0.0009]	*1.0e-04* *[0.3824 0.0031 0.0011 0.0013]	*1.0e-04* *[0.1744 0.0009 0.0003 0.0005]

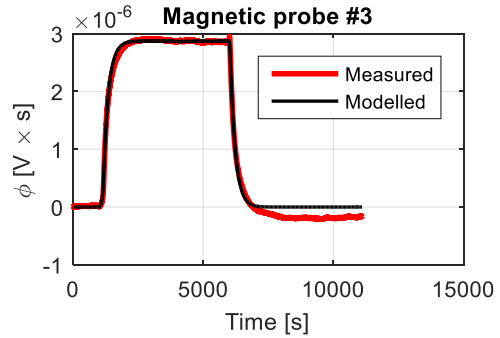
$$x[n+1] = Ax[n] + Bu_{horizontal}[n]$$
$$y_{horizontal}[n] = Cx[n]$$

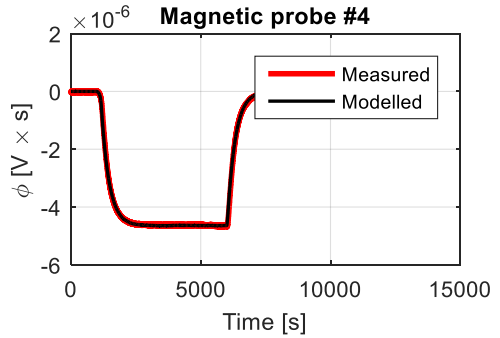
	mirnv9	mirnv10	mirnv11	mirnv12
x_0	$\begin{bmatrix} 0.0001 \\ 0.0015 \\ 0.0135 \\ -0.0045 \end{bmatrix}$	$\begin{bmatrix} 0.0001 \\ 0.0122 \\ -0.0042 \\ -0.0026 \end{bmatrix}$	$\begin{bmatrix} 0.0003 \\ 0.0089 \\ -0.0012 \\ 0.0104 \end{bmatrix}$	$\begin{bmatrix} -0.0002 \\ -0.0010 \\ -0.0118 \\ 0.0035 \end{bmatrix}$
A	$\begin{bmatrix} 0.9854 & -0.0100 & -0.0024 & -0.0041 \\ -0.0418 & 0.9476 & -0.0552 & -0.0867 \\ 0.0040 & 0.0030 & 0.8126 & -0.5872 \\ 0.0119 & 0.1033 & 0.5672 & 0.8079 \end{bmatrix}$	$\begin{bmatrix} 0.9921 & -0.0019 & -0.0029 & 0.0014 \\ -0.0100 & 0.8107 & -0.5821 & -0.0003 \\ 0.0074 & 0.5790 & 0.8081 & 0.1007 \\ 0.0428 & -0.0296 & -0.0934 & 0.9092 \end{bmatrix}$	$\begin{bmatrix} 0.9849 & -0.0085 & -0.0062 & 0.0045 \\ -0.0446 & 0.8552 & -0.4275 & 0.0607 \\ 0.0224 & 0.3938 & 0.8094 & 0.4208 \\ 0.0317 & -0.1666 & -0.3879 & 0.8713 \end{bmatrix}$	$\begin{bmatrix} 0.9929 & -0.0441 & -0.0068 & -0.0120 \\ -0.0137 & 0.8813 & -0.0429 & -0.0549 \\ -0.0061 & -0.0155 & 0.7965 & -0.6088 \\ 0.0166 & 0.0665 & 0.5261 & 0.7680 \end{bmatrix}$
B	$\begin{bmatrix} 0 \\ -0.0001 \\ -0.0012 \\ -0.0003 \end{bmatrix}$	$1.0e-03 * \begin{bmatrix} 0.0052 \\ -0.2924 \\ -0.1013 \\ -0.2193 \end{bmatrix}$	$1.0e-03 * \begin{bmatrix} 0.0193 \\ -0.3272 \\ -0.5058 \\ -0.4650 \end{bmatrix}$	$\begin{bmatrix} 0 \\ 0 \\ -0.0024 \\ -0.0001 \end{bmatrix}$
C	*1.0e-04* *[0.2916 0.0016 0.0013 −0.0005]	*1.0e-04* *[0.8227 0.0002 −0.0008 0.0001]	*1.0e-04* *[0.5518 0.0038 −0.0012 0.0005]	*1.0e-04* *[0.1707 0.0025 0.0005 −0.0006]

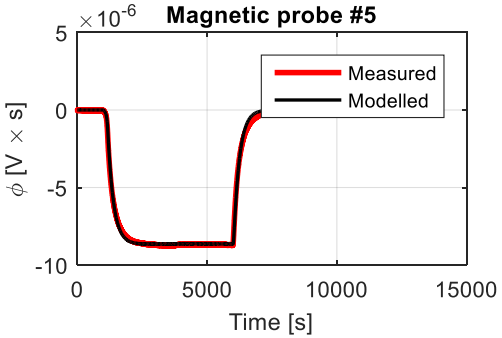
Shot #44503

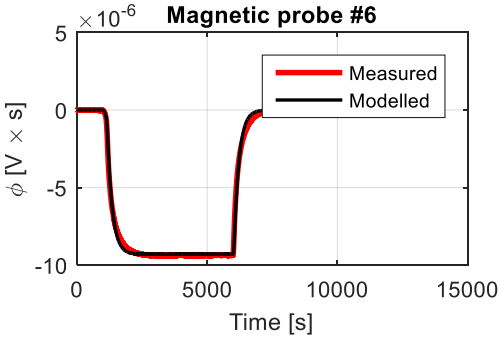

Magnetic probe #1
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]

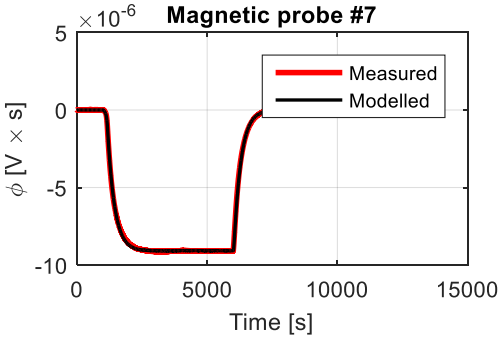

Magnetic probe #2
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]

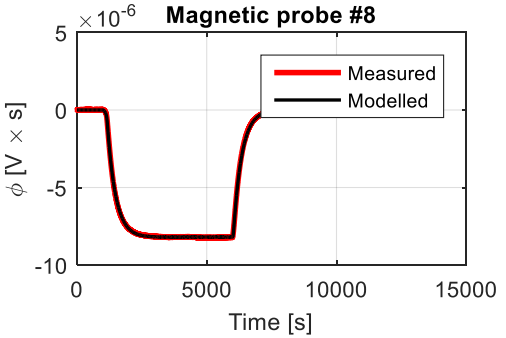

Magnetic probe #3
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]

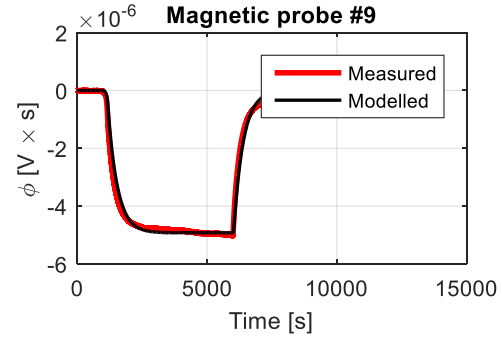

Magnetic probe #4
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]

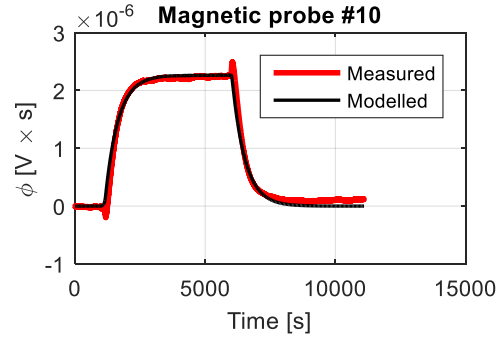

Magnetic probe #5
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]

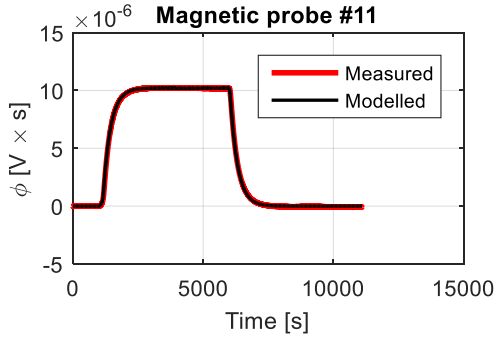

Magnetic probe #6
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]

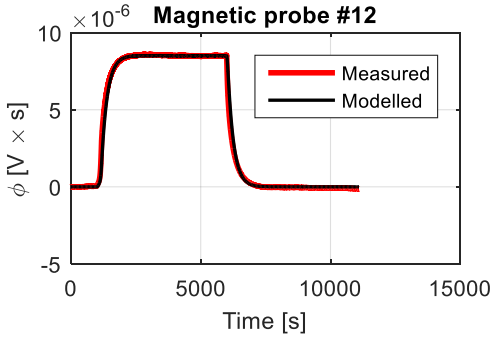

Magnetic probe #7
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]


Magnetic probe #8
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]


Magnetic probe #9
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]


Magnetic probe #10
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]


Magnetic probe #11
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]


Magnetic probe #12
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]

Shot #44503

$$x[n+1] = Ax[n] + Bu_{primario}[n]$$
$$y_{primario}[n] = Cx[n]$$

	mirnv1	mirnv2	mirnv3	mirnv4
x_0	$[-4.2670e-06]$	$[-3.6560e-05]$	$[9.6572e-05]$	$[-3.9196e-04]$
A	[0.9938]	[0.9961]	[0.9949]	[0.9967]
B	$[-3.7145e-06]$	$[-1.6091e-06]$	$[-2.3011e-06]$	$[1.2275e-06]$
C	$[9.9948e-05]$	$[1.5655e-04]$	$[3.9682e-05]$	$[7.8925e-05]$

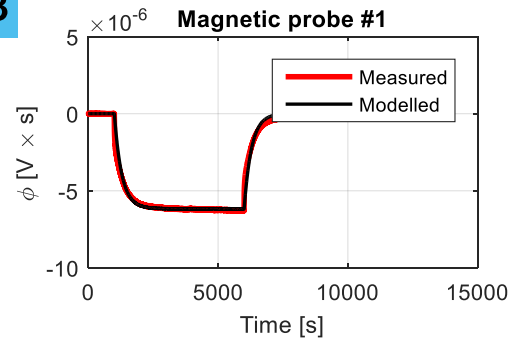
$$x[n+1] = Ax[n] + Bu_{primario}[n]$$
$$y_{primario}[n] = Cx[n]$$

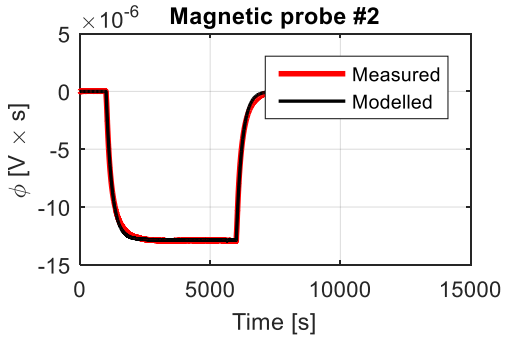
	mirnv5	mirnv6	mirnv7	mirnv8
x_0	$[-2.5227e-04]$	$[1.0415e-04]$	$[-2.1947e-05]$	$[1.2819e-04]$
A	[0.9955]	[0.9948]	[0.9963]	[0.9969]
B	$[2.1295e-06]$	$[2.7208e-06]$	$[1.6216e-06]$	$[1.1930e-06]$
C	$[1.1387e-04]$	$[1.1087e-04]$	$[1.2924e-04]$	$[1.3444e-04]$

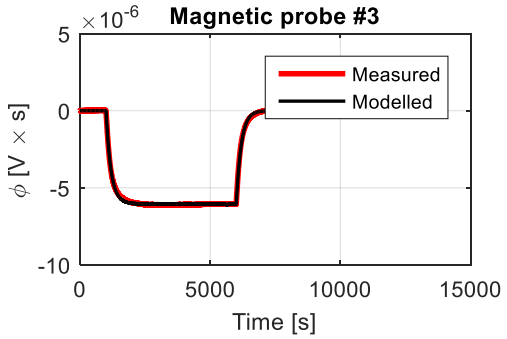
$$x[n+1] = Ax[n] + Bu_{primario}[n]$$
$$y_{primario}[n] = Cx[n]$$

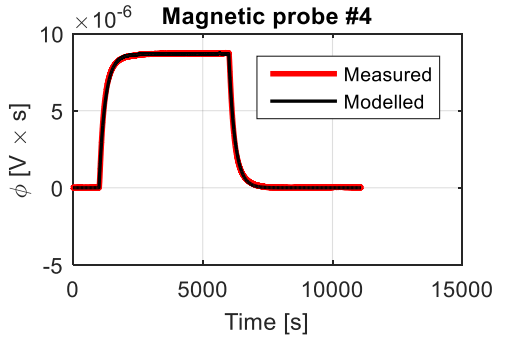
	mirnv9	mirnv10	mirnv11	mirnv12
x_0	$[-8.6324e-06]$	$[-9.2918e-05]$	$[-7.3422e-05]$	$[-1.2908e-05]$
A	[0.9973]	[0.9980]	[0.9965]	[0.9956]
B	$[1.1342e-06]$	$[-5.3643e-07]$	$[-1.3952e-06]$	$[-2.6599e-06]$
C	$[7.4447e-05]$	$[5.3425e-05]$	$[1.6005e-04]$	$[8.8590e-05]$

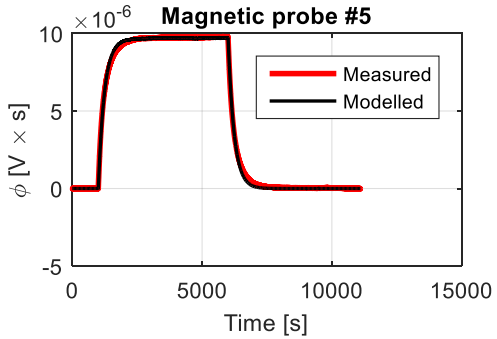
Shot #44473

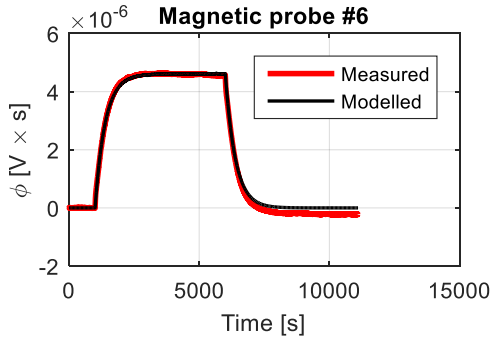

Magnetic probe #1
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]

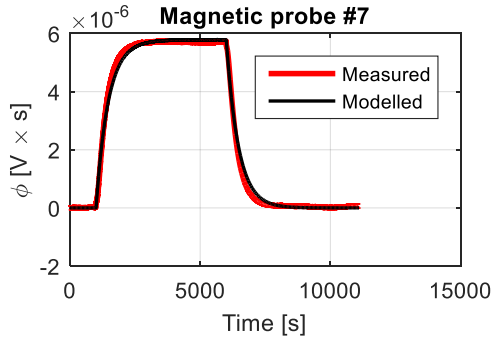

Magnetic probe #2
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]

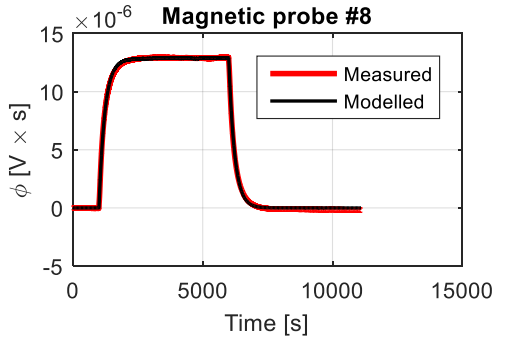

Magnetic probe #3
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]

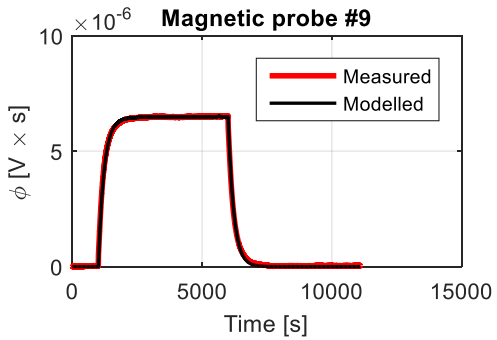

Magnetic probe #4
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]

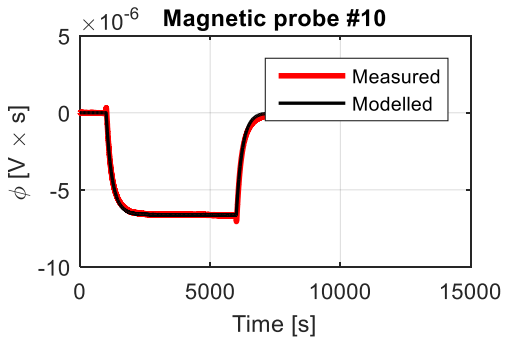

Magnetic probe #5
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]

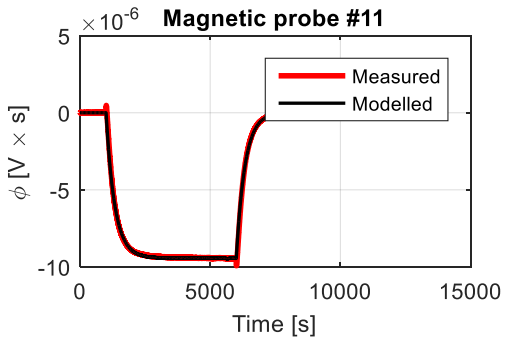

Magnetic probe #6
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]

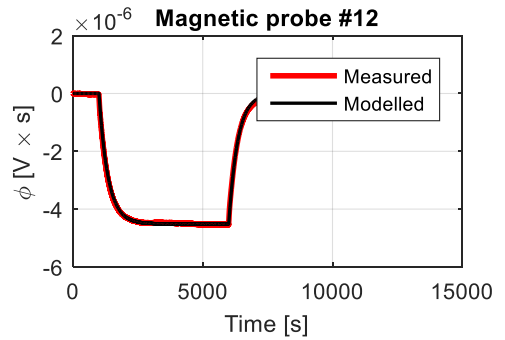

Magnetic probe #7
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]


Magnetic probe #8
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]


Magnetic probe #9
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]


Magnetic probe #10
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]


Magnetic probe #11
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]


Magnetic probe #12
×10^-6
Measured
Modelled
ϕ [V × s]
Time [s]

Shot #44473

$$x[n+1] = Ax[n] + Bu_{vertical}[n]$$
$$y_{vertical}[n] = Cx[n]$$

	mirnv1	mirnv2	mirnv3	mirnv4
x_0	$[-5.0782e-05]$	$[8.9336e-06]$	$[-2.1129e-05]$	$[1.9132e-04]$
A	[0.9965]	[0.9954]	[0.9948]	[0.9958]
B	$[-7.3730e-07]$	$[-9.3380e-07]$	$[-1.1501e-06]$	$[8.2278e-07]$
C	$[8.6369e-05]$	$[1.8519e-04]$	$[8.1457e-05]$	$[1.3135e-04]$

$$x[n+1] = Ax[n] + Bu_{vertical}[n]$$
$$y_{vertical}[n] = Cx[n]$$

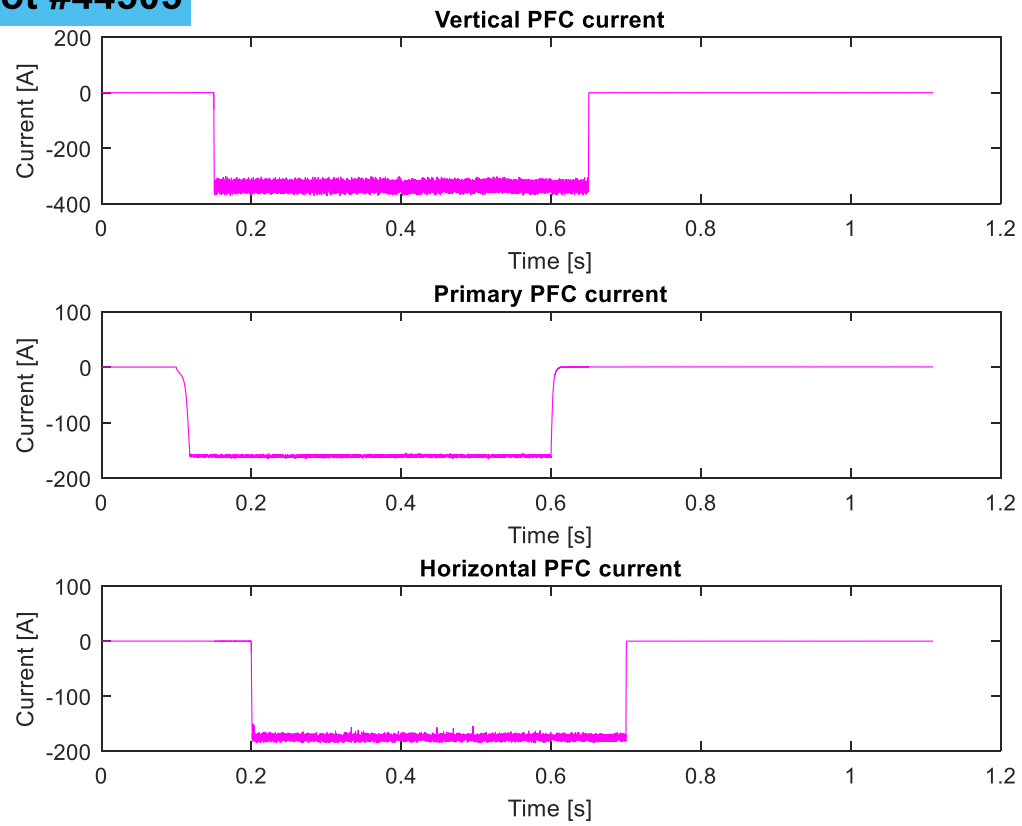
	mirnv5	mirnv6	mirnv7	mirnv8
x_0	$[7.1308e-06]$	$[-1.6334e-05]$	$[-2.2075e-06]$	$[-1.7549e-05]$
A	$[0.9957]$	$[0.9974]$	$[0.9979]$	$[0.9956]$
B	$[8.5511e-07]$	$[4.1116e-07]$	$[3.1284e-07]$	$[8.9309e-07]$
C	$[1.4290e-04]$	$[8.5269e-05]$	$[1.1650e-04]$	$[1.8800e-04]$

$$x[n+1] = Ax[n] + Bu_{vertical}[n]$$
$$y_{vertical}[n] = Cx[n]$$

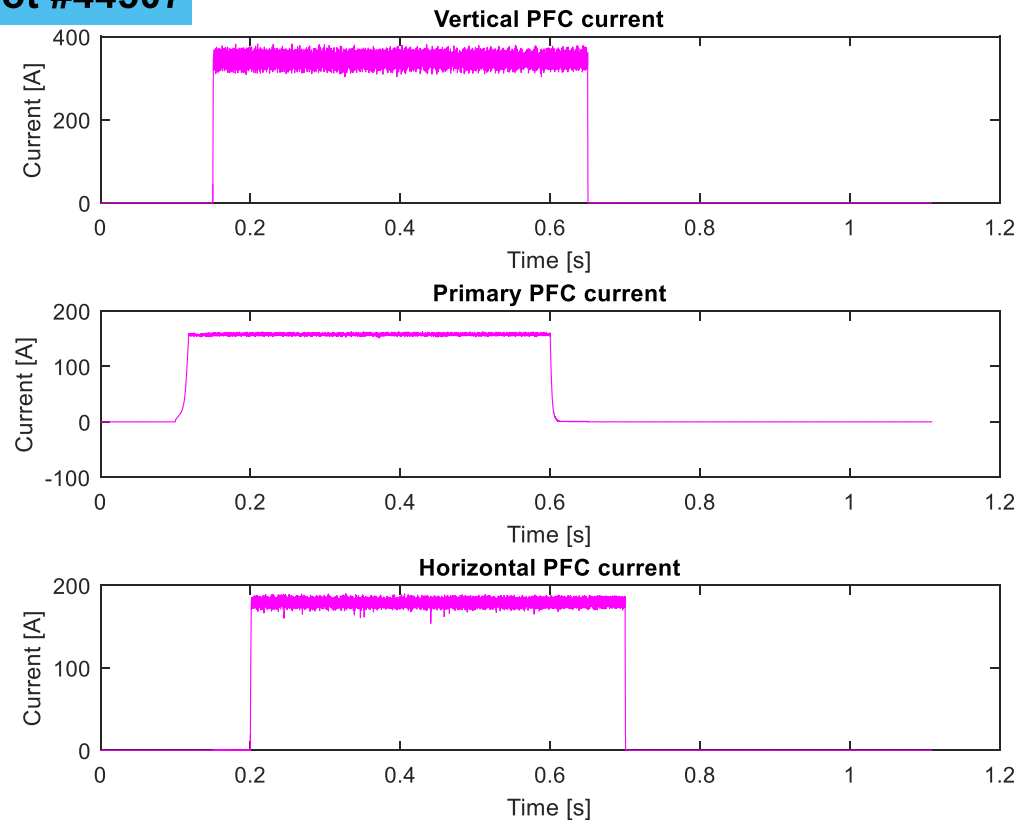
	mirnv9	mirnv10	mirnv11	mirnv12
x_0	$[3.5897e-05]$	$[6.9882e-05]$	$[4.5795e-05]$	$[-3.2860e-05]$
A	$[0.9954]$	$[0.9956]$	$[0.9970]$	$[0.9971]$
B	$[9.7768e-07]$	$[-8.0569e-07]$	$[-4.7293e-07]$	$[-4.8623e-07]$
C	$[8.9416e-05]$	$[1.0574e-04]$	$[1.7697e-04]$	$[7.9094e-05]$

Testing shots

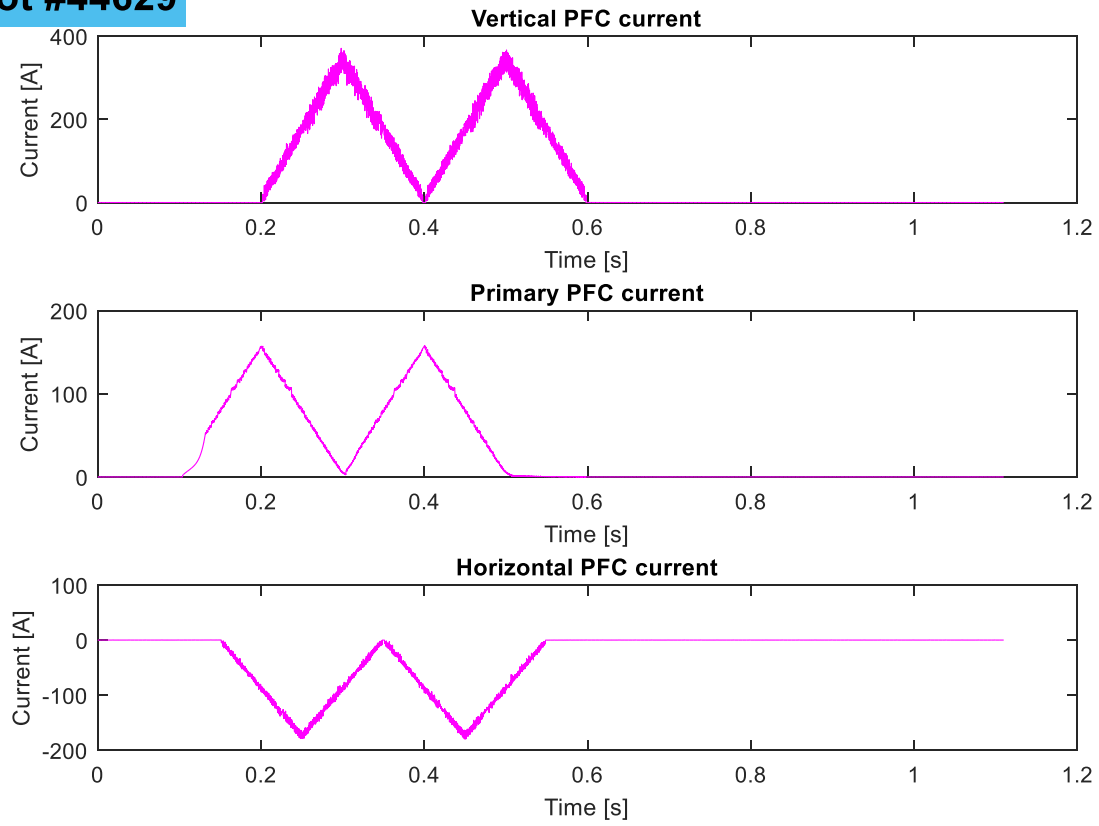
Shot #44505



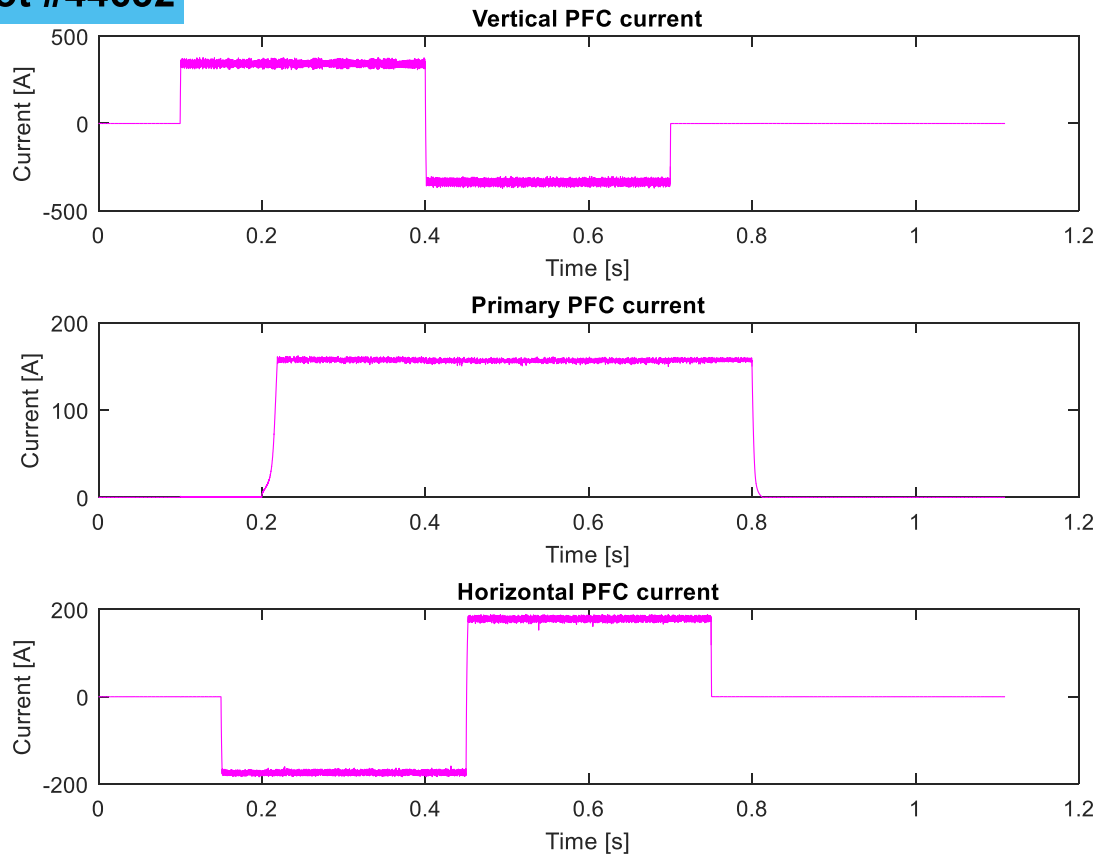
Shot #44507



Shot #44629

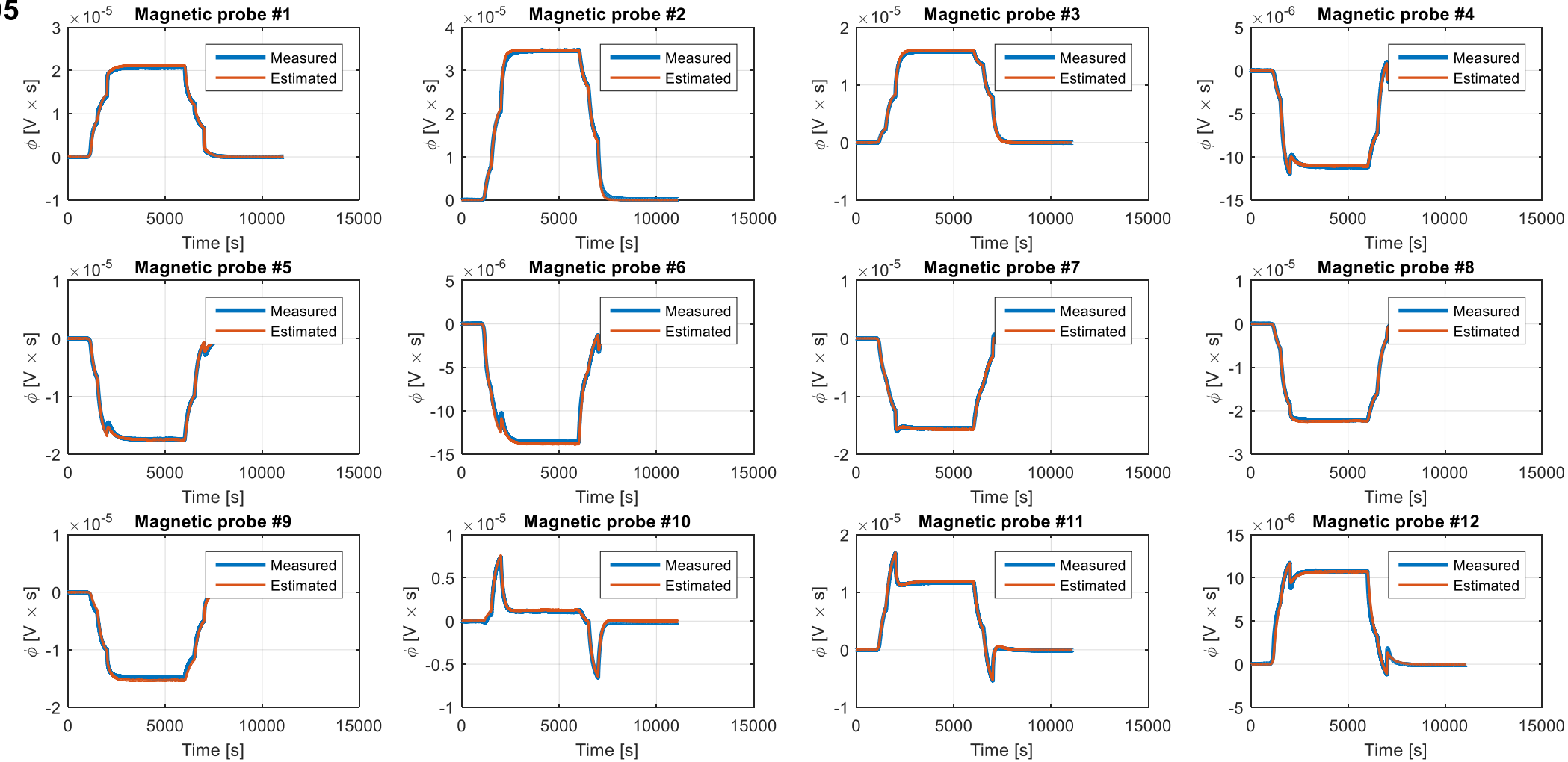


Shot #44632



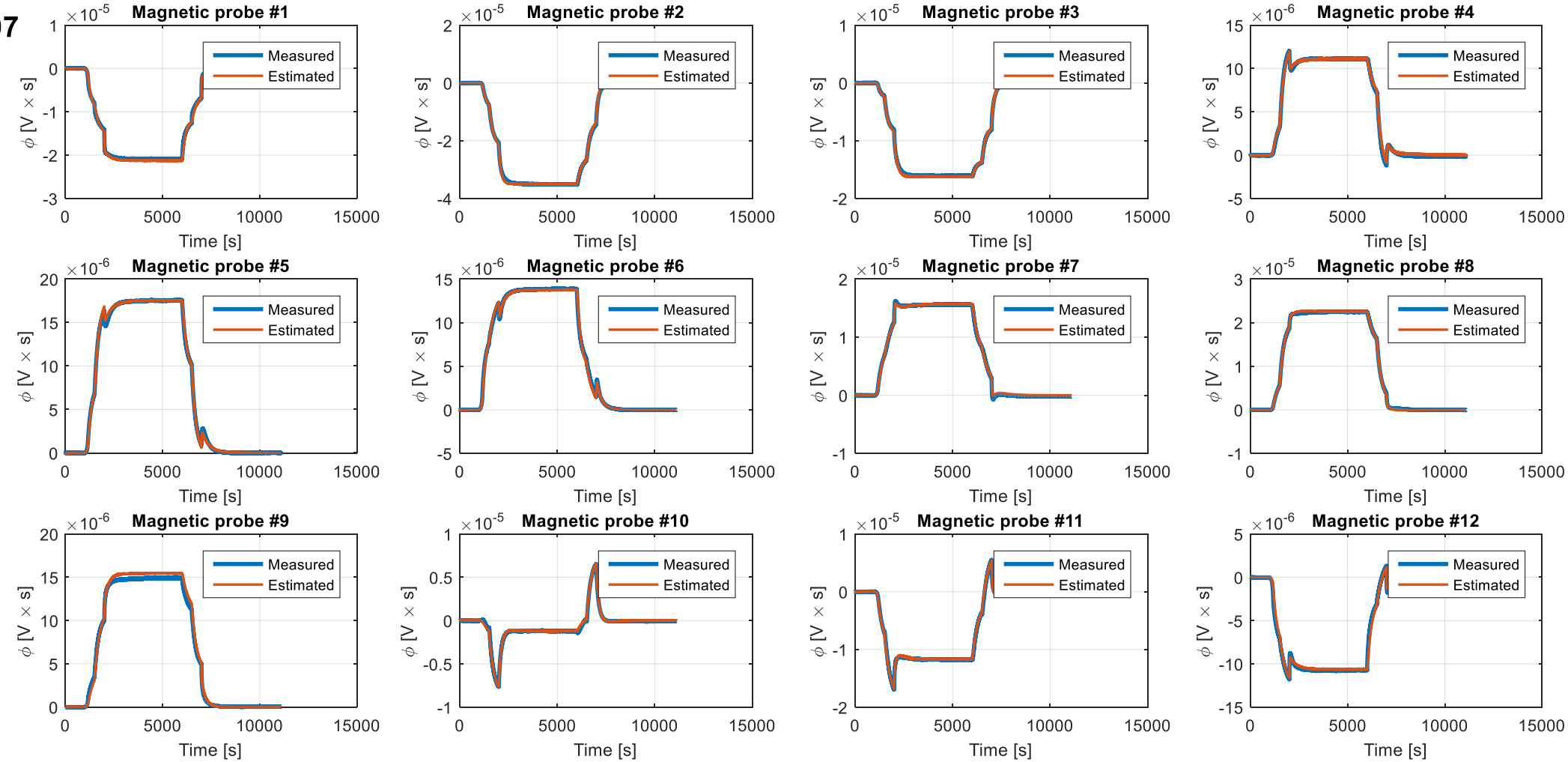
$$y_{estimated}[n] = y_{vertical}[n] + y_{horizontal}[n] + y_{primario}[n]$$

Shot #44505



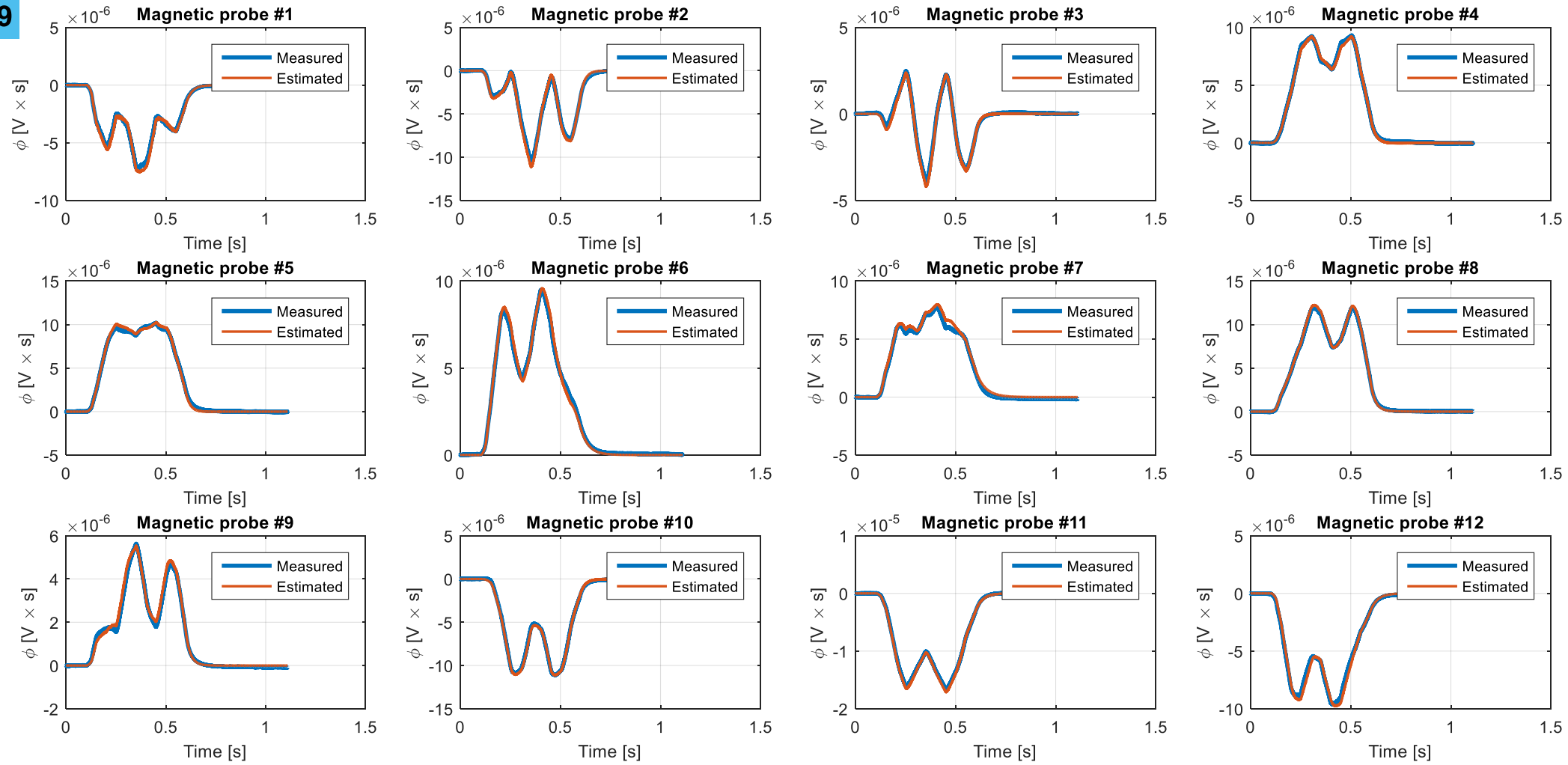
$$y_{estimated}[n] = y_{vertical}[n] + y_{horizontal}[n] + y_{primario}[n]$$

Shot #44507



$$y_{estimated}[n] = y_{vertical}[n] + y_{horizontal}[n] + y_{primario}[n]$$

Shot #44629



$$y_{estimated}[n] = y_{vertical}[n] + y_{horizontal}[n] + y_{primario}[n]$$

Shot #44632