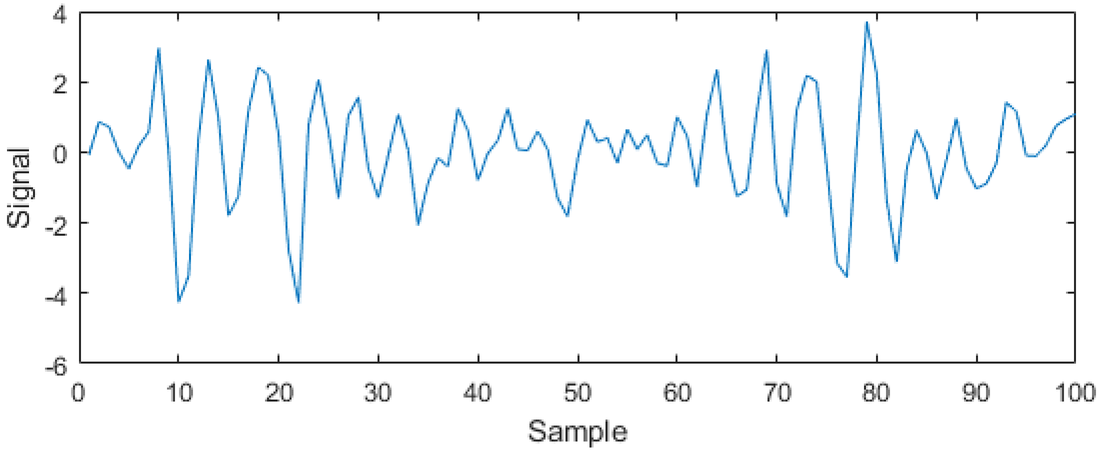
EE512 – Applied Biomedical Signal Processing

Practical session – Linear Models I

Experiment 1: comparing AR estimation methods

a) The answer should include a plot similar to:



b) The answer should include the code for all four estimation approaches, and the results obtained. The resulting parameters for (i) will be, for example:

i. Autocorrelation method (`aryule`): $a_1 = -0.5639,\ a_2 = 0.7474$

ii. Yule-Walker with biased autocorrelation (xcorr): $a_1 = -0.5639,\ a_2 = 0.7474$

The answer should explain that we get the same results, because the first approach (`aryule`) is described as solving the Yule-Walker equations (autocorrelation method) using Levinson-Durbin, which is fully (mathematically) equivalent to linear prediction (MSE criterion) via directly solving the Yule-Walker equations using the biased autocorrelation for R_{xx}.

c) The resulting parameters for (ii) will be, for example:

i. Covariance method (`arcov`): $a_1 = -0.5674,\ a_2 = 0.7542$

ii. Linear prediction (MSE): $a_1 = -0.5674,\ a_2 = 0.7542$

The answer should explain that we get the same results because the two approaches are simply different implementations of the same method, i.e. linear prediction by MSE minimization using the covariance method.

d) The answer should report the estimated AR parameters for each size, and observe that the two approaches give closer results when the size becomes larger. This is because the difference between the two approaches is in how the boundary values are used; the larger the signal, the smaller the relative contribution from the boundaries.

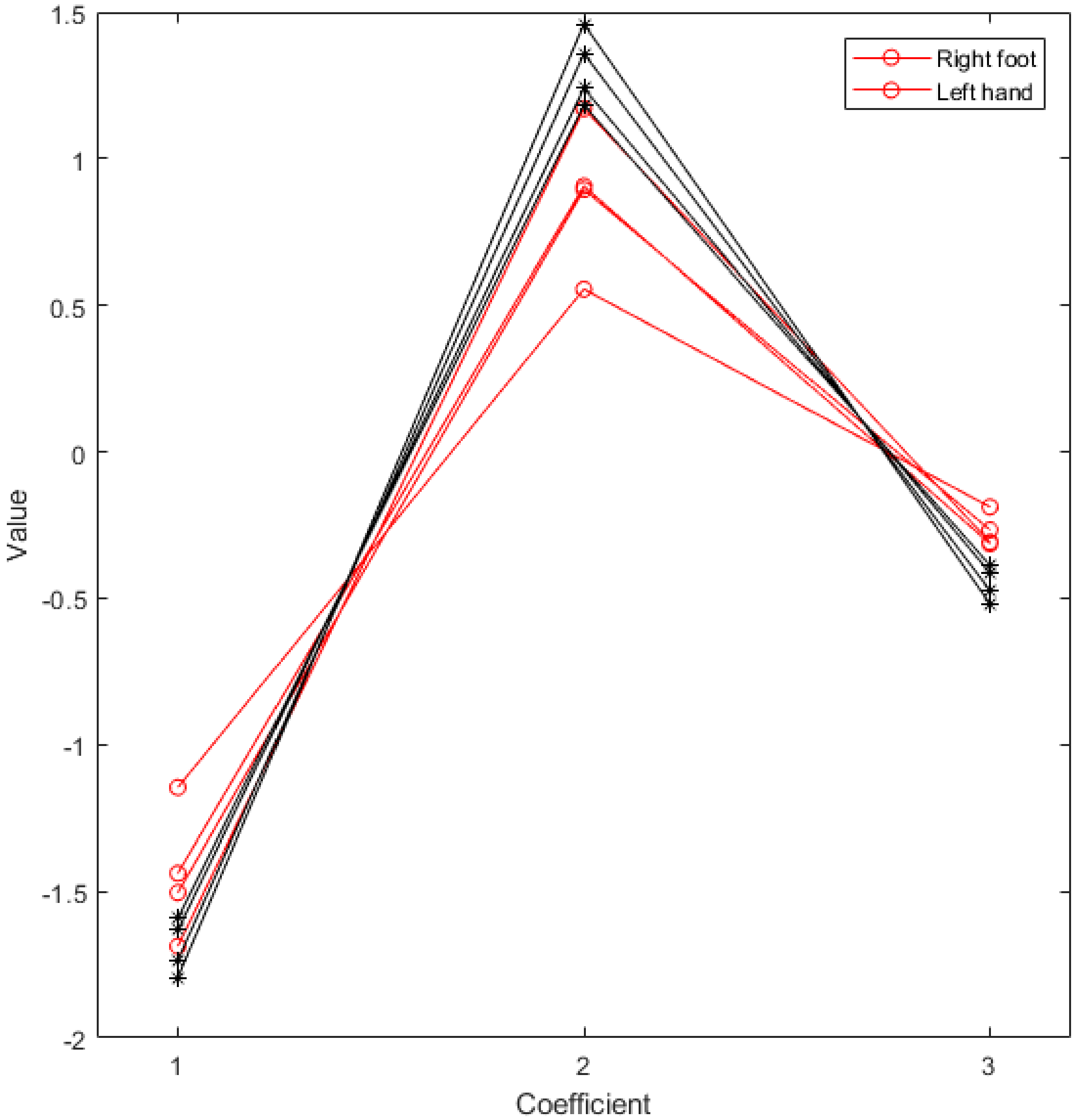
Experiment 2: classifying EEG signals

a) The answer should report the model order results, which are:

Left-hand:	7	7	3	9
Right-foot:	4	4	4	3

It should then note that the orders tend to be larger for left-hand, suggesting a difference. For a common choice, the smallest value found (3) should be considered, to ensure that all models have significant AR coefficients.

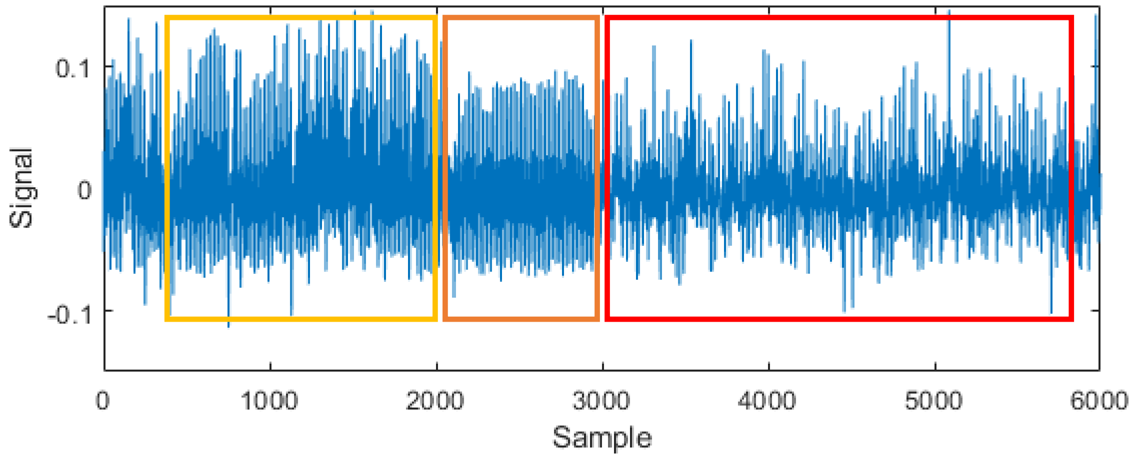
b) The answer should report the obtained estimates, which are probably best visualized in a plot such as:



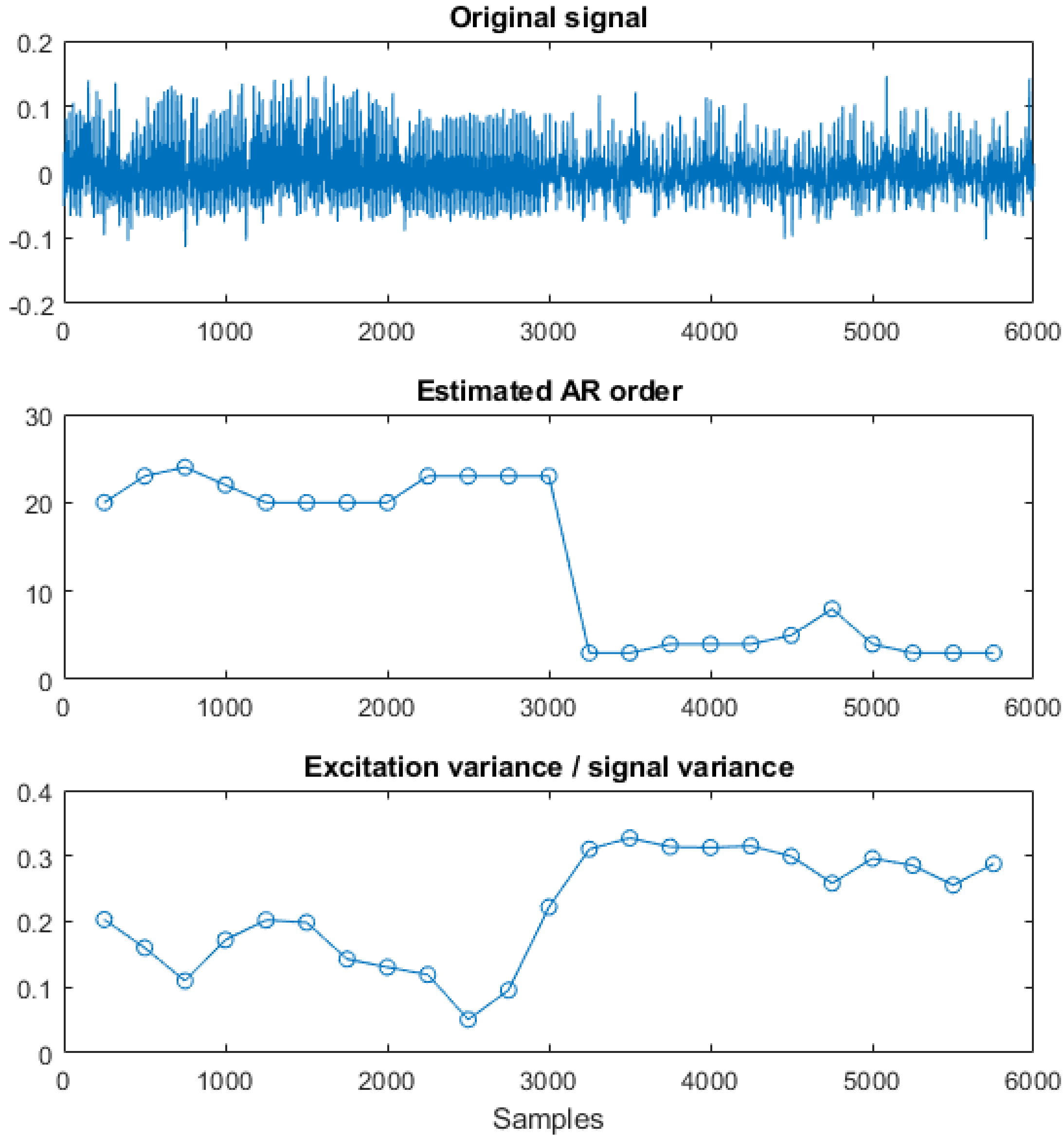
It should then note that based on visual inspection, the separation appears best defined in the second and especially the third coefficient.

Experiment 3: AR model evolution over time

a) The answer should present a plot of the signal and either mark the desired periods (like below) or present zoomed window plots.

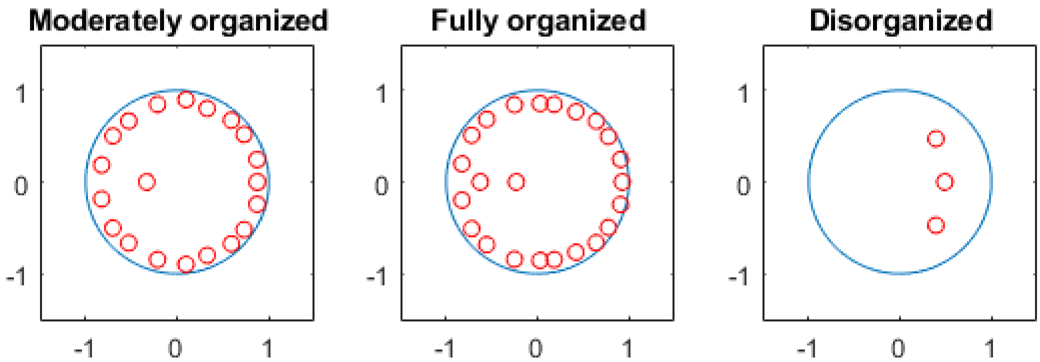


b) The required plots should look like the following:



The answer should then discuss that the more organized the signal is, the closer it will be to a weighted sum of sinusoids, and thus the better it will be described by an AR model without excitation. As we see in the plots, when the signal is organized, the model order is high and the excitation variance is a smaller proportion of the full signal variance, which is indeed consistent with the expectation described above. When the signal becomes less organized, the model order drops and the proportion of variance occupied by the excitation rises, consistent with a transition to a more disorganized regime where the excitation becomes more dominant with respect to a more regular dependence on past samples (i.e. its AR "character").

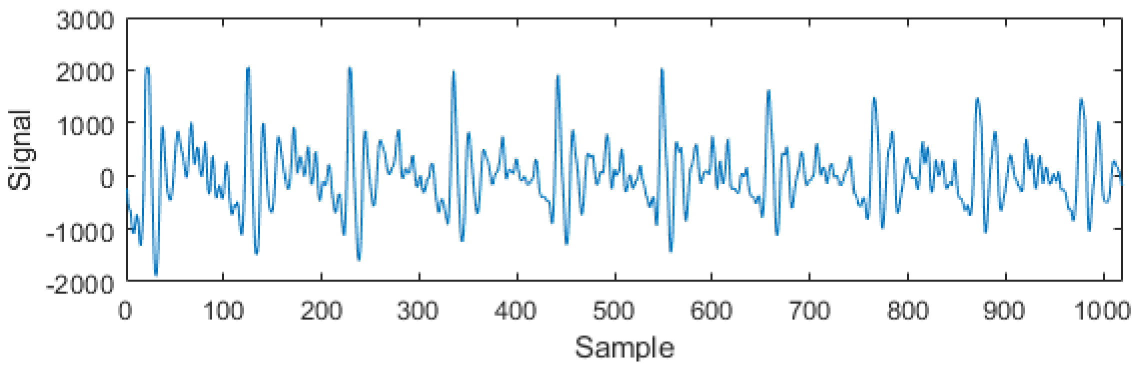
c) The required plots should look like the following:



For commenting, the answer may report the mean (or median) magnitude of the poles, which is 0.8726, 0.8790 and 0.6131 for the three periods above. It should be seen that the more organized the signal is, the closer the poles are to the unit circle. In an ideal case of a pure sum of sinusoids (a "very organized" signal), the poles would lie on the unit circle.

Experiment 4: recovering the excitation (whitening filter)

a) The answer should present a plot of the signal such as:

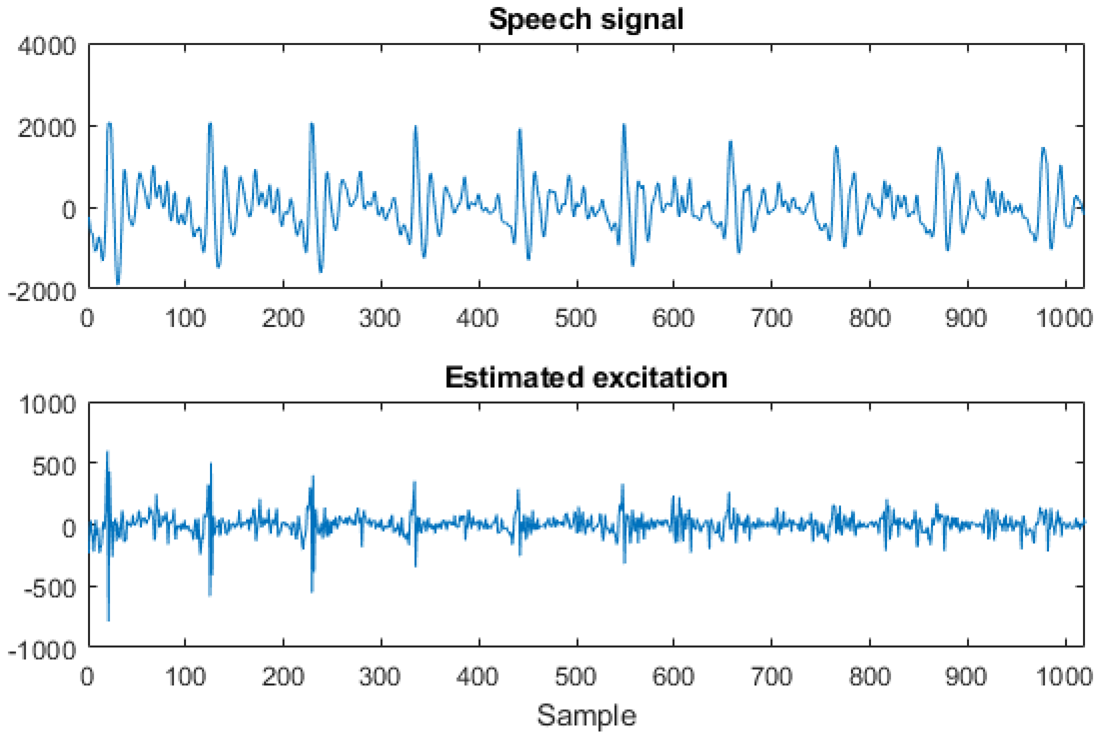


b) The answer should report a model order estimate of 22. The obtained parameters may be reported as well (though unnecessary):

-2.0558	0.3583	-0.2873	0.0423	-0.0871	0.0219
1.5961	-0.3649	0.1928	0.0032	0.1346	-0.005
-0.5002	0.0379	-0.0110	0.0596	-0.1590	
-0.0640	0.2904	-0.1573	0.0248	0.0498	

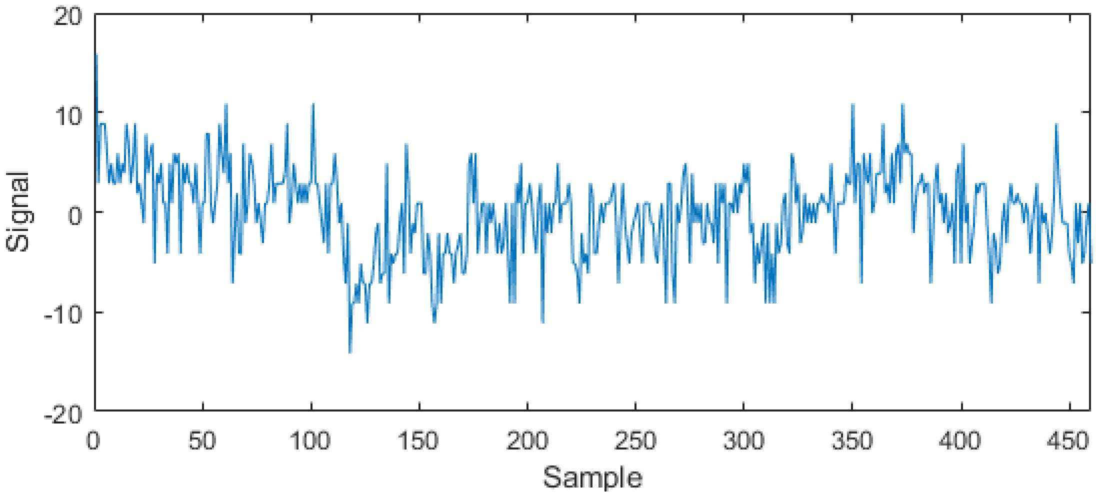
c) The answer should explain that the AR parameters in **a** correspond to the coefficients of the polynomial $H(z) = \frac{1}{B(z)} = \frac{1}{1+\sum_{k=1}^{p} a(k)z^{-k}}$ which is the filter function relating the input excitation signal with the output signal x. To obtain the input excitation signal, we can then simply apply the inverse filter $B(z)$ to x, which is exactly what the `filter` function is doing in the proposed command.

d) The answer should present a plot such as:



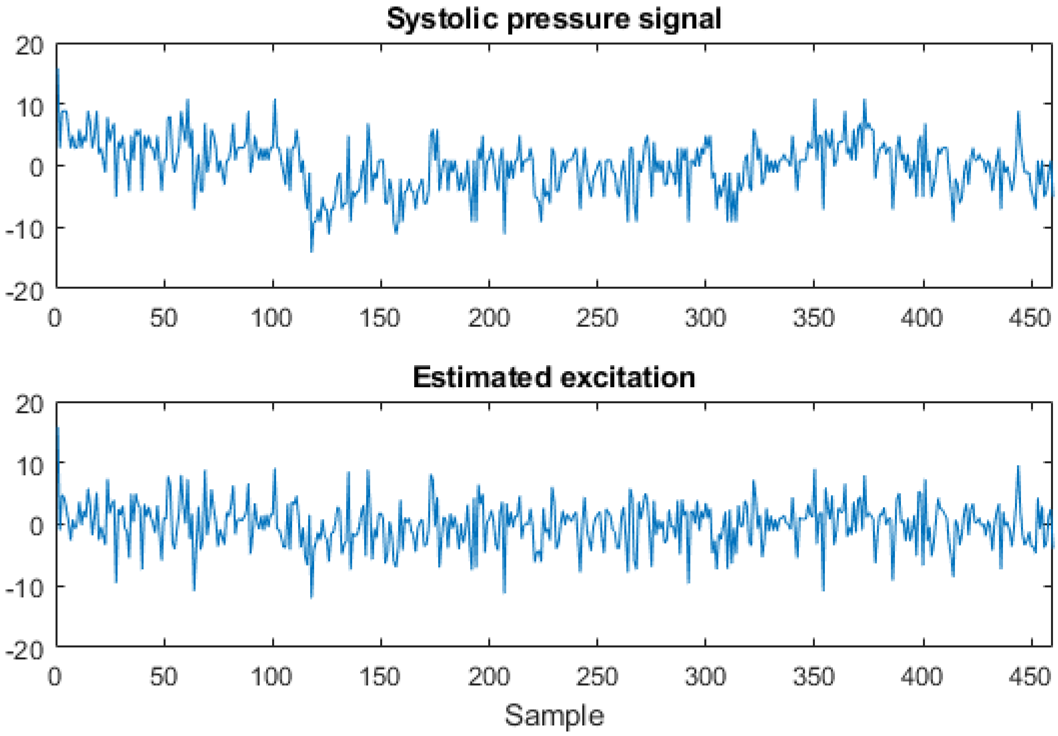
It can be commented that visually, the excitation shows impulses appearing at regular intervals (which correspond to pressure waves generated by the vocal cords). Nonetheless, the whiteness test states that the proportion of autocorrelation estimates larger than the 5% threshold is 0.0236, which is below the typical threshold of 0.05.

e) Repeating the procedure, the answer should present a plot of the signal such as:



The answer should then report a model order estimate of 4. The obtained parameters may be reported as well: -0.2419 -0.2131 -0.1088 -0.1337

A plot of the excitation should be made, such as:



It can be commented that visually, the excitation appears considerably more random than for the speech signal. Accordingly, the whiteness test states that the proportion of autocorrelation estimates larger than the 5% threshold is 0.0065, which is considerably lower than for the speech.