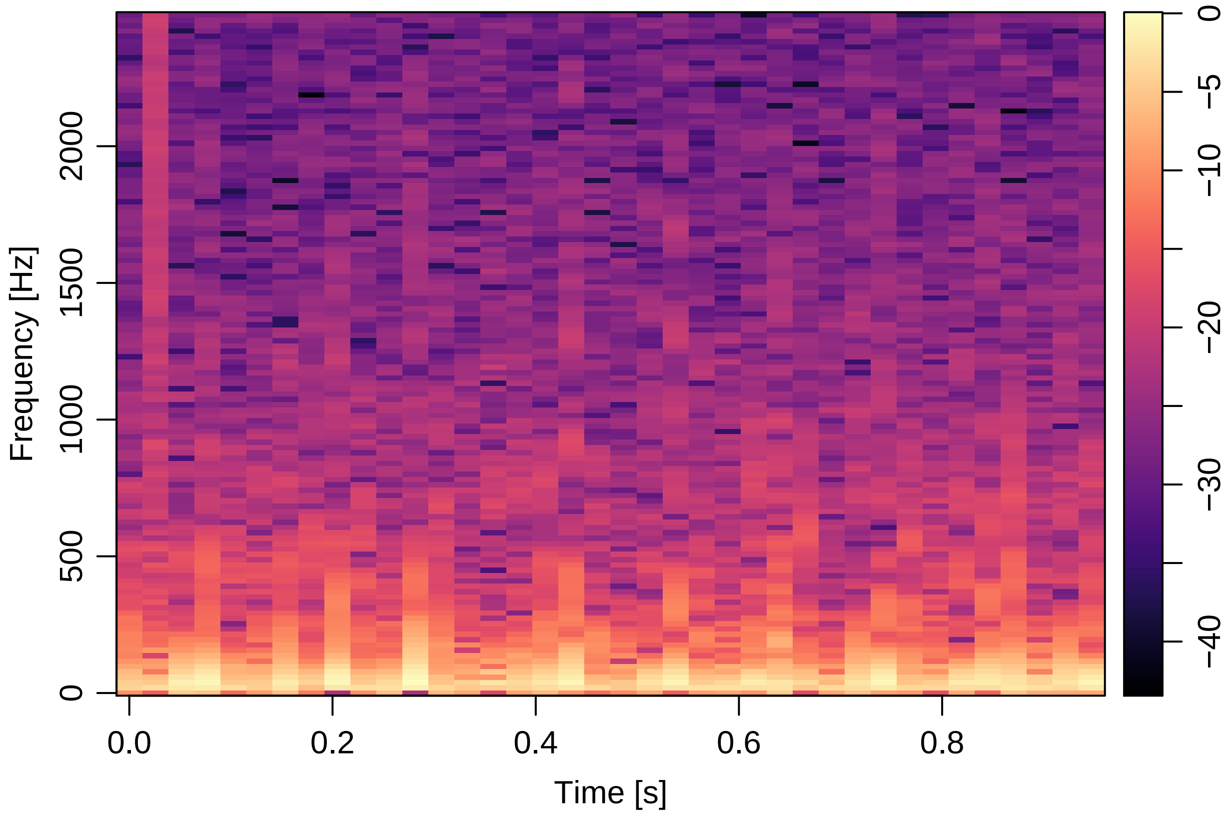
Coupling Modulation

RRC

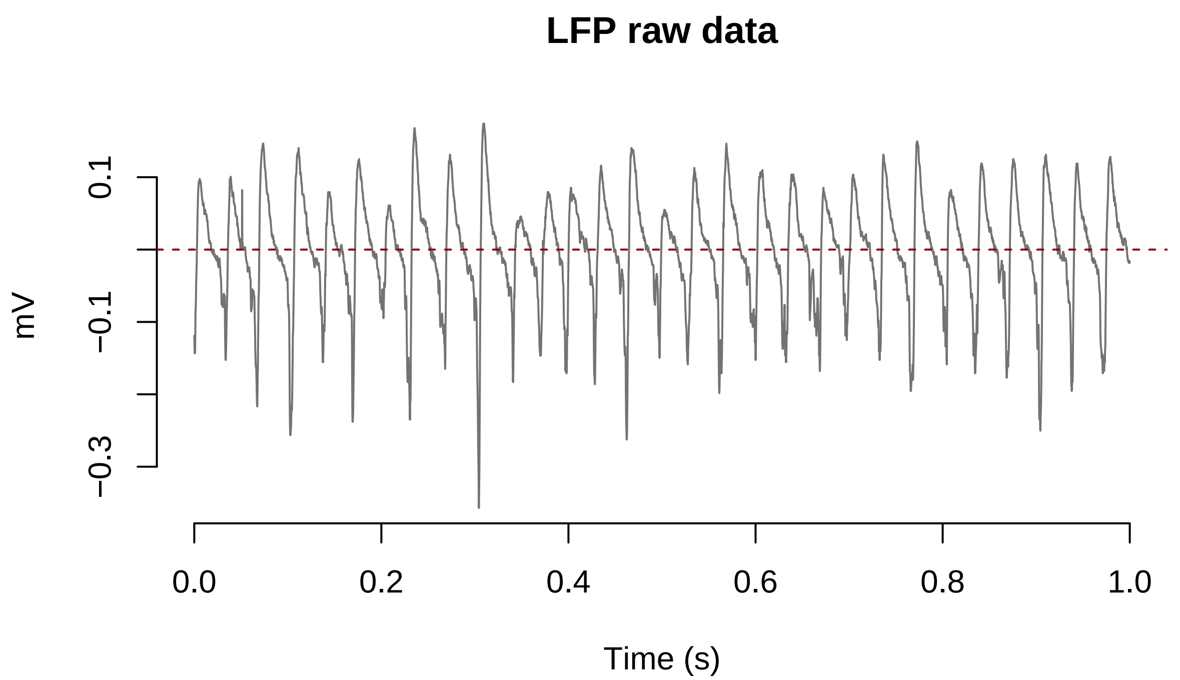
1. Read the data

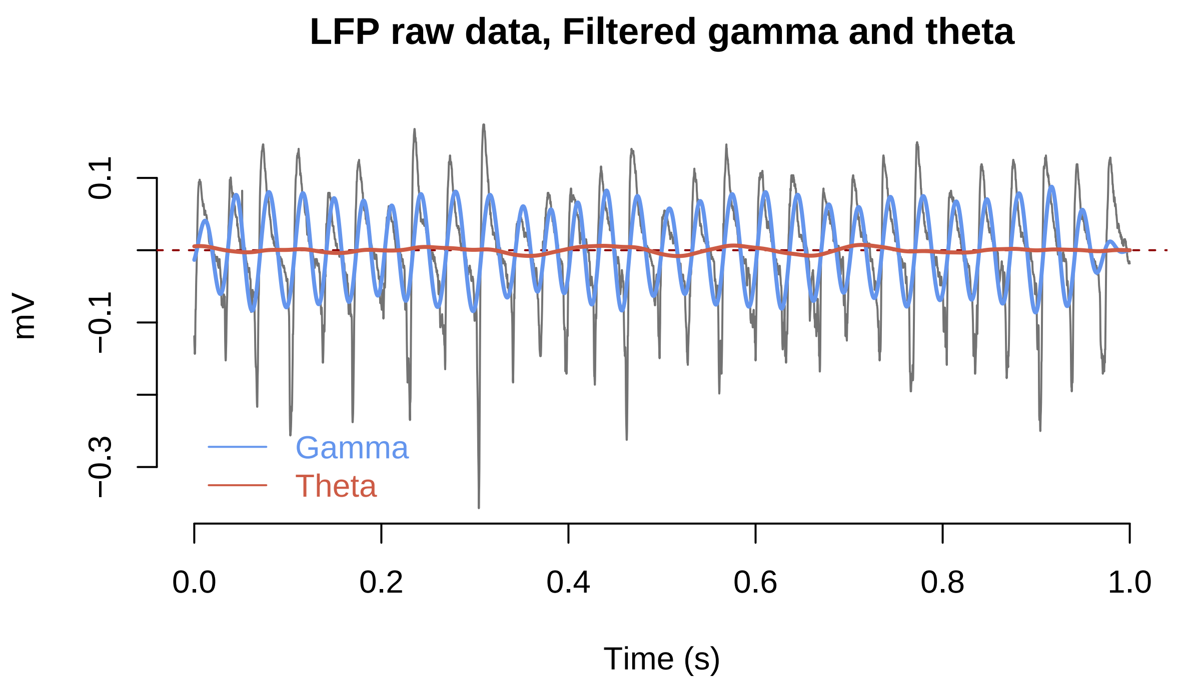
Spectrogram of the raw time series

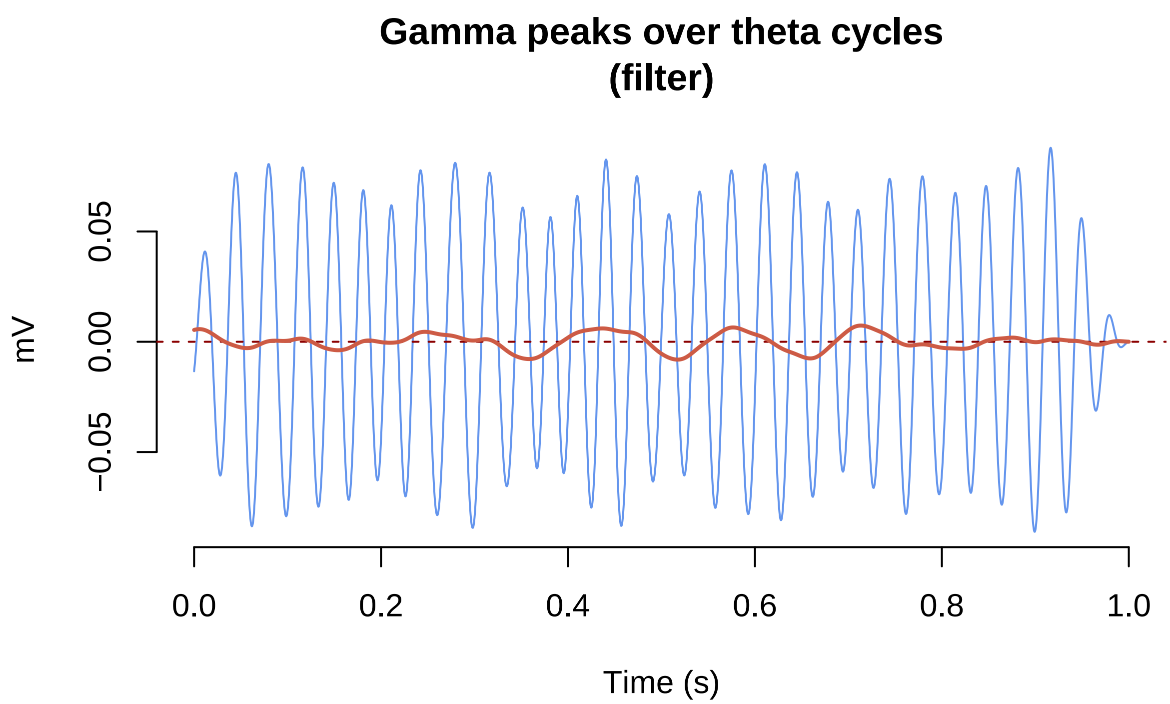


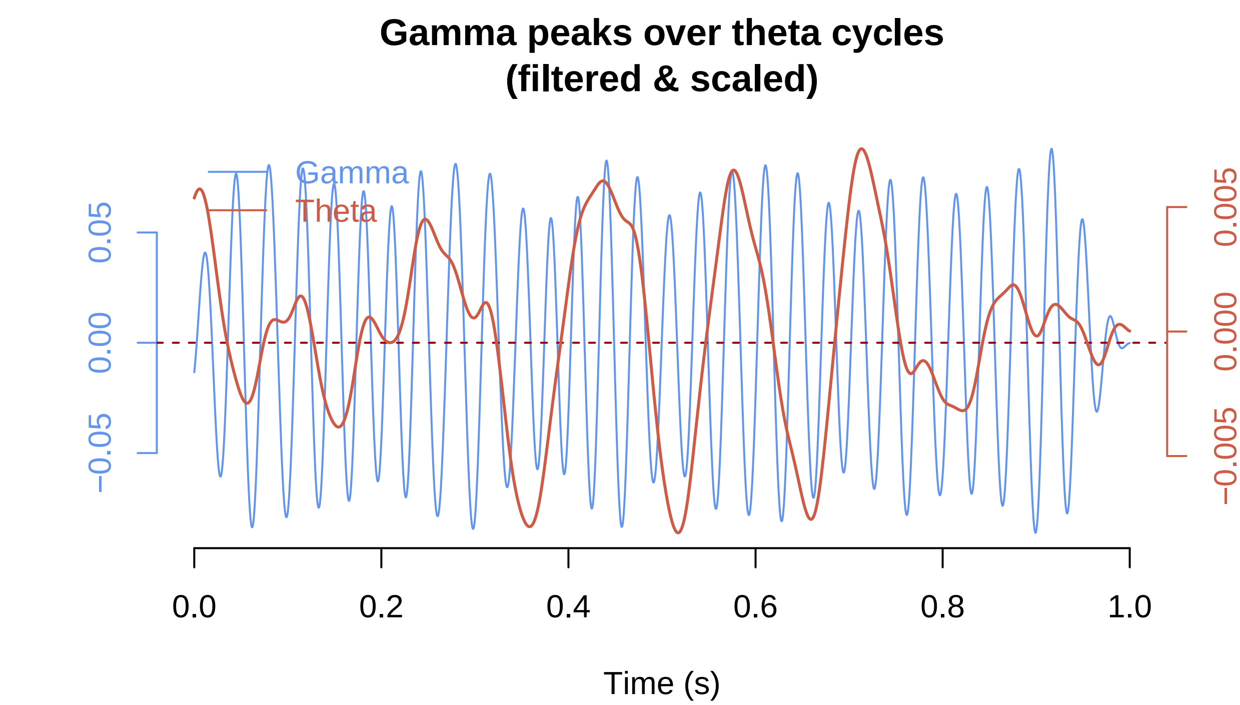
PCA of the raw time series

Filtering of the data

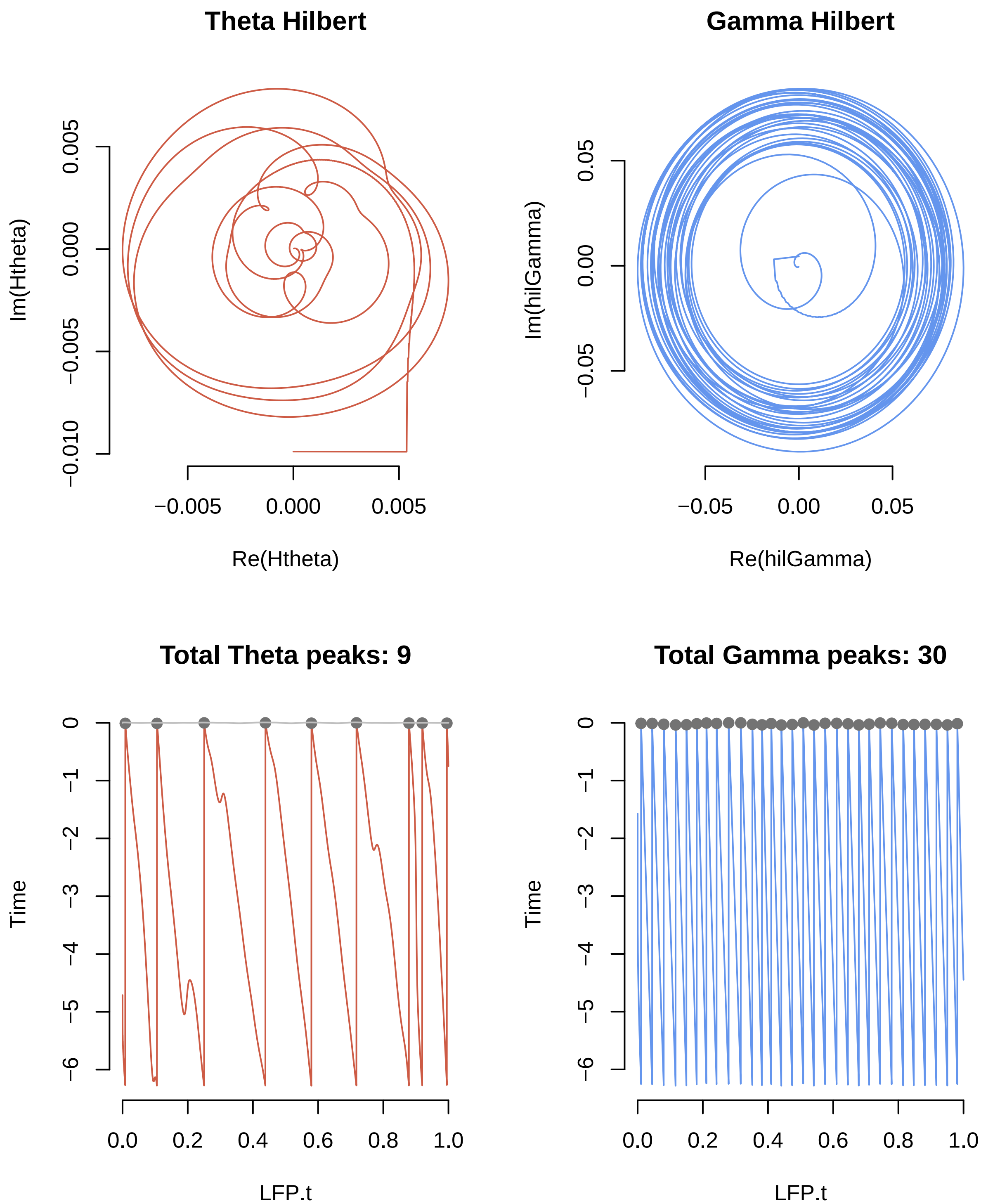


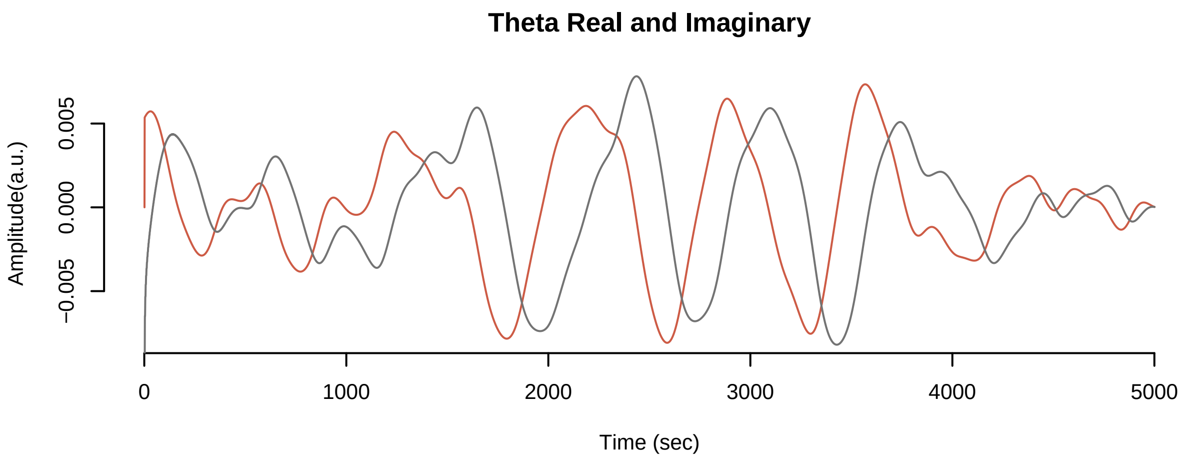


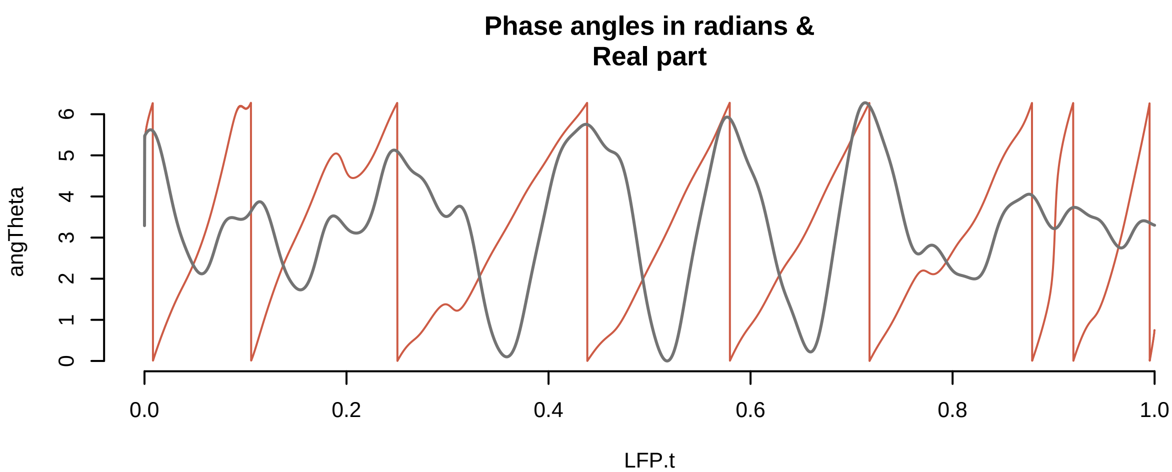


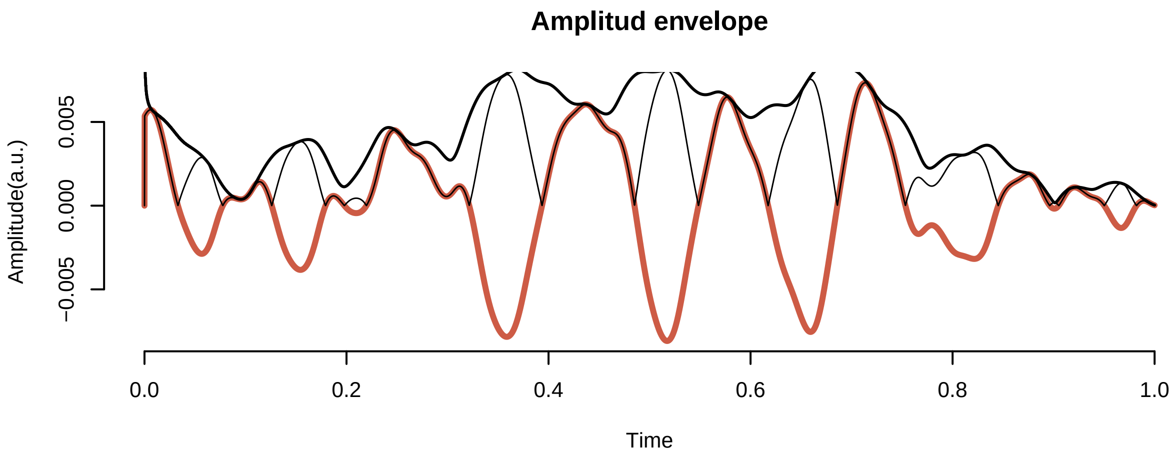



```
## [1] "Gamma peaks per Theta cycle: 3.33333333333333"
```

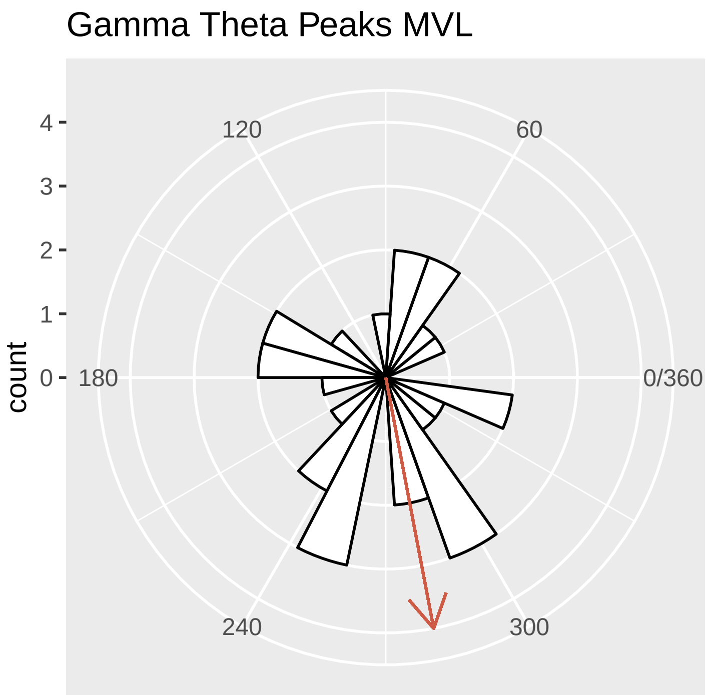

Theta Hilbert
Im(Htheta)
0.005
0.000
−0.005
−0.010
−0.005
0.000
0.005
Re(Htheta)
Gamma Hilbert
Im(hilGamma)
0.05
0.00
−0.05
−0.05
0.00
0.05
Re(hilGamma)
Total Theta peaks: 9
Time
0
−1
−2
−3
−4
−5
−6
0.0
0.2
0.4
0.6
0.8
1.0
LFP.t
Total Gamma peaks: 30
Time
0
−1
−2
−3
−4
−5
−6
0.0
0.2
0.4
0.6
0.8
1.0
LFP.t

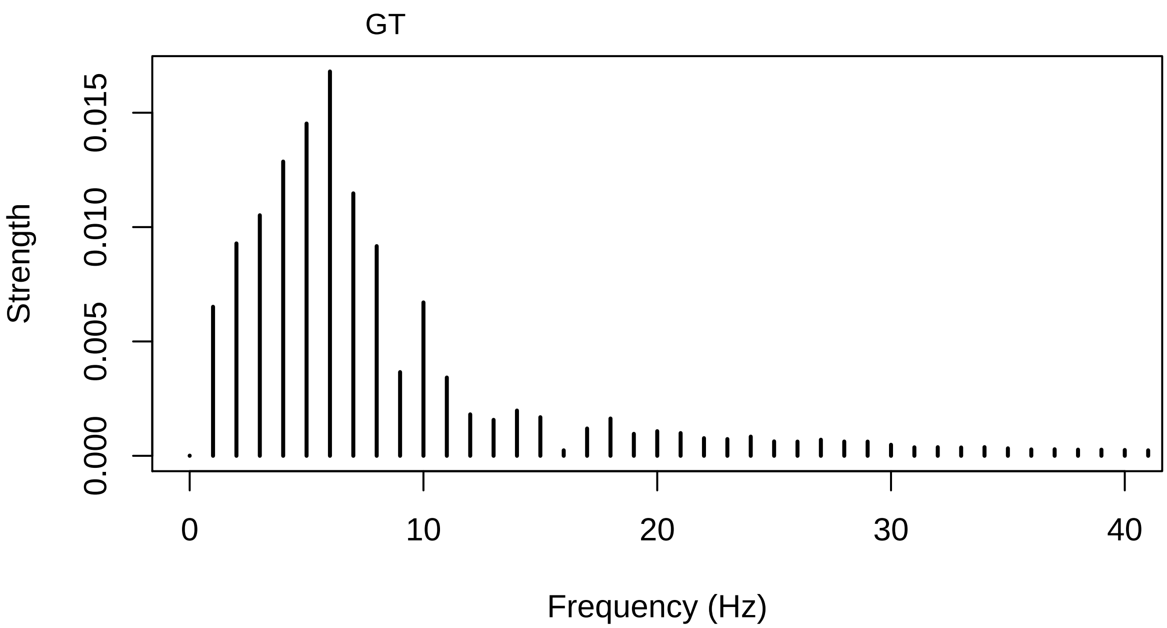







```
## [1] 6.614265e-05
```





`matlab` code

```
# ------------------------------------------------------------- #
# CALCULO DE LA POTENCIA DE LA ENVOLVENTE
fr5 <- 5;
tmp <- abs(f-fr5);
[~, inx4] <- min(tmp);
fr10 <- 10;
tmp <- abs(f-fr10);
```

```
[~, inx10] <- min(tmp);

fr20 <- 20;
tmp <- abs(f-fr20);
[~, inx20] <- min(tmp);
fr80 <- 60;
tmp <- abs(f-fr80);
[~, inx80] <- min(tmp);

for n <- inx4:inx10
    Area <- (espectro2(n)+espectro2(n+1))/2*(f(n+1)-f(n));
end
GenvPow <- sum(Area);

# -------------------------------------------------------------- #
# CALCULO DEL PICO MAXIMO DE FRECUENCIA
cerotes <- zeros(length(espectro2(1:inx4-1)),1);# prepara un vector de 0 para aislar theta
newespectro2 <- vertcat(cerotes,espectro2(inx4:inx10));# concatena los ceros al rango de theta
[~,inxMaxE] <- max(newespectro2);
GenvMax <- f(inxMaxE);

cerotes <- zeros(length(espectro1(1:inx20-1)),1);# prepara un vector de 0 para aislar gamma
newespectro1 <- vertcat(cerotes,espectro1(inx20:inx80));# concatena los ceros al rango de gamma
[~,inxMaxG] <- max(newespectro1);
GMax <- f(inxMaxG);


# -------------------------------------------------------------- #
# GRAFICAS
subplot(2,1,1)
plot(f,espectro1,f,espectro2)
axis([0 80 0 0.005]) # de 0 a 80 Hz y de 0 a 15e-3 mV2
subplot(2,1,2)
plot(time,gamma,time,envPeak,time,theta)
axis([0 1 -0.35 0.35]) # de 0 a 1 s y de -0.1 a 0.1 mV
shg

#  Cross-correlation Gamma Envelope-Theta
[acor,lag]  <-  xcorr(envolvente,theta,'coeff');      # correlacion de las senyales

[cor,I]  <-  max((abs(acor)));# coeficiente de correlacion entre ambas senales
Peaklag  <-  lag(I);#  Posicicion del pico maximo
timeDiff  <-  Peaklag/Fs; #  lag en s del pico maximo
Peaklagms  <-  timeDiff*1000; #  Peak lag en ms.

plot(lag/Fs,acor)
axis([-0.5 0.5 -0.6 0.6])
shg

# Autocorrelation of gamma signal and Rhythmicity
[acor,lag]  <-  xcorr(gamma,500);      # correlacion de las senyales
Nacor  <-  acor/max(acor); # Normaliza el maximo de autocorrelation
halfcor  <-  Nacor(fix((length(acor)/2)):end); # mitad de la correlacion
```

```
halftime  <-  (lag(fix((length(lag)/2)):end))/Fs;# time of the corresponding lag in sec

cor1  <-  halfcor; # redefine la variable halfcor

peaks  <-  findpeaks(cor1);    # picos
troughs  <-  findpeaks(-cor1); # valles

A  <-  peaks(2) + 1;        # identificacion del primer pico
B  <-  - troughs(1) + 1;  # identificacion del segundo valle

Cr <- (A-B)/(A+B);

# plot(halftime,halfcor)
# axis([0 0.1 -1  1])
# shg
```

```
library()
# Determine the strength of phase-locking (and its statistical significance) between pairs of quasiperi
# https://besjournals.onlinelibrary.wiley.com/doi/10.1111/2041-210X.12188
# phase.sync
```

Measurements to implement

Phase syncrony (PS) https://www.rdocumentation.org/packages/synchrony/versions/0.3.8/topics/phase.sync
https://github.com/tgouhier/synchrony
Cross-frequenct phase synchrony (CFS)
Phase-amplitude coupling (PAC)
http://visbrain.org/auto_examples/objects/plot_pac_obj.html
https://github.com/EtienneCmb/tensorpac
https://pactools.github.io/auto_examples/plot_comodulogram.html
PAC-t https://github.com/muntam/TF-PAC
https://www.nature.com/articles/s41598-019-48870-2
https://srcole.github.io/2016/03/06/pac/
https://github.com/srcole/qwm/blob/master/pac/Estimating%20PAC.ipynb

1.Amplitud y frecuencia de l
a senal envolvente
1. Acoplamiento de la senal enviolmente cin ka senak principla
1. Acoplamiento de la senal evolvent eocn los potenciales de accion

References

Cross-Frequency Phase–Phase Coupling between Theta and Gamma Oscillations in the Hippocampus
Mariano A. Belluscio, Kenji Mizuseki, Robert Schmidt, Richard Kempter and György Buzsáki
Journal of Neuroscience 11 January 2012, 32 (2) 423-435; DOI: https://doi.org/10.1523/JNEUROSCI.4122-11.2012
https://www.jneurosci.org/content/32/2/423
https://towardsdatascience.com/four-ways-to-quantify-synchrony-between-time-series-data-b99136c4a9c9

Further resources

1. (R for Matlab users)[http://mathesaurus.sourceforge.net/octave-r.html]
2. mat2r from matconv
3. (Numpy for R users)[http://mathesaurus.sourceforge.net/r-numpy.html]
4. (Fourier Transform: A R tutorial)[http://www.di.fc.ul.pt/~jpn/r/fourier/fourier.html]