Dhirubhai Ambani Institute of Information and Communication Technology

ADSP

LAB – 4 : Instantaneous Frequency, Hilbert Transform and Hilbert Envelope

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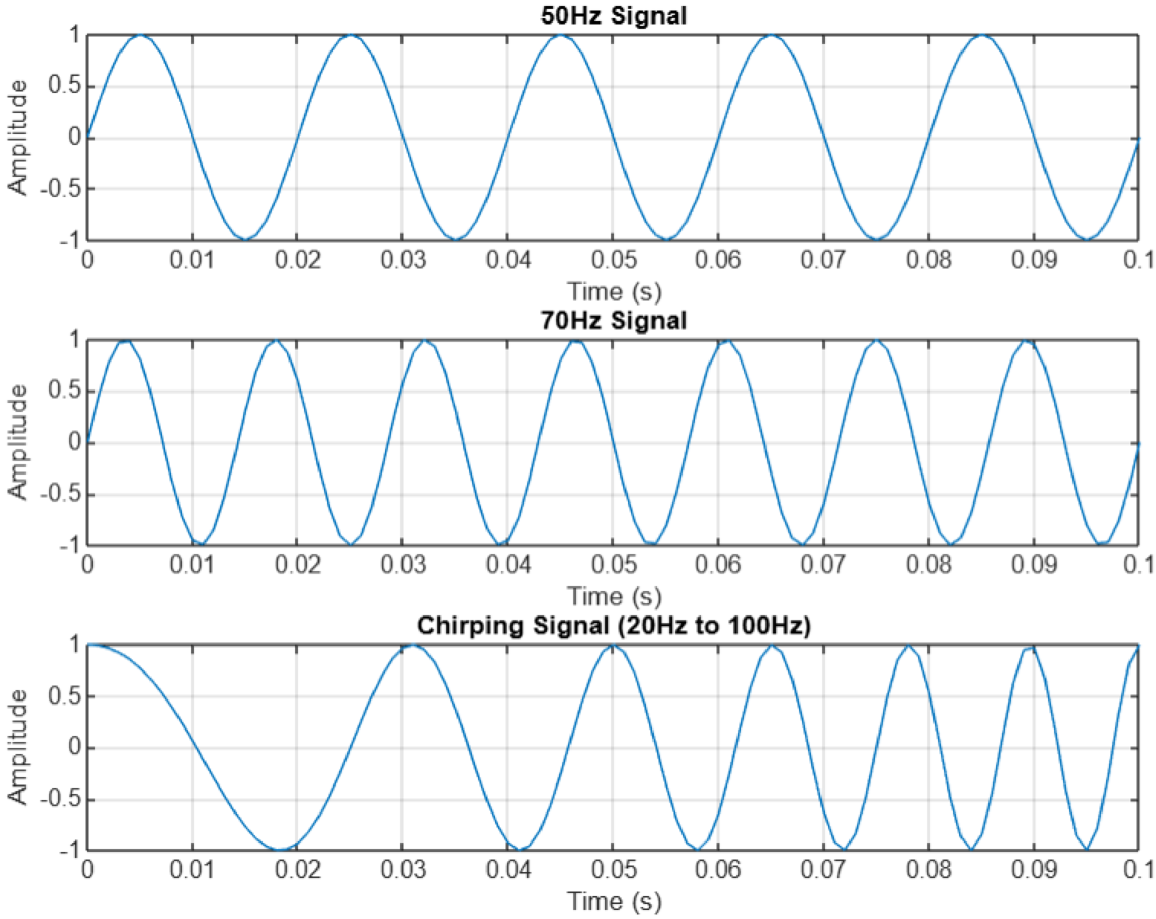
EXERCISES

1.) Plot 50Hz, 70Hz and Chirping signal.

CODE:

```
% 202411012
% Plotting raw signal

fs = 1000;  % Sampling frequency (Hz)
t = 0:1/fs:0.1;  % Time vector (0 to 0.1 sec)
f_50 = 50;  % Signal frequency (Hz)
signal_50Hz = sin(2*pi*f_50*t);  % Sine wave signal


% 70 Hz signal
f_70 = 70;
signal_70Hz = sin(2*pi*f_70*t);


% Chirping signal
% It is a signal where the frequency is sweeping from
% 20 Hz to 100 Hz
f_0 = 20;
f_1 = 100;
chirp_signal = chirp(t, f_0, max(t), f_1);
```

```
% Plot all 3 signals
figure
subplot(3, 1, 1)
plot(t, signal_50Hz)
title('50Hz Signal')
xlabel('Time (s)')
ylabel('Amplitude')
grid on

subplot(3, 1, 2)
plot(t, signal_70Hz)
title('70Hz Signal')
xlabel('Time (s)')
ylabel('Amplitude')
grid on

subplot(3, 1, 3)
plot(t, chirp_signal)
title('Chirping Signal (20Hz to 100Hz)')
xlabel('Time (s)')
ylabel('Amplitude')
grid on
```

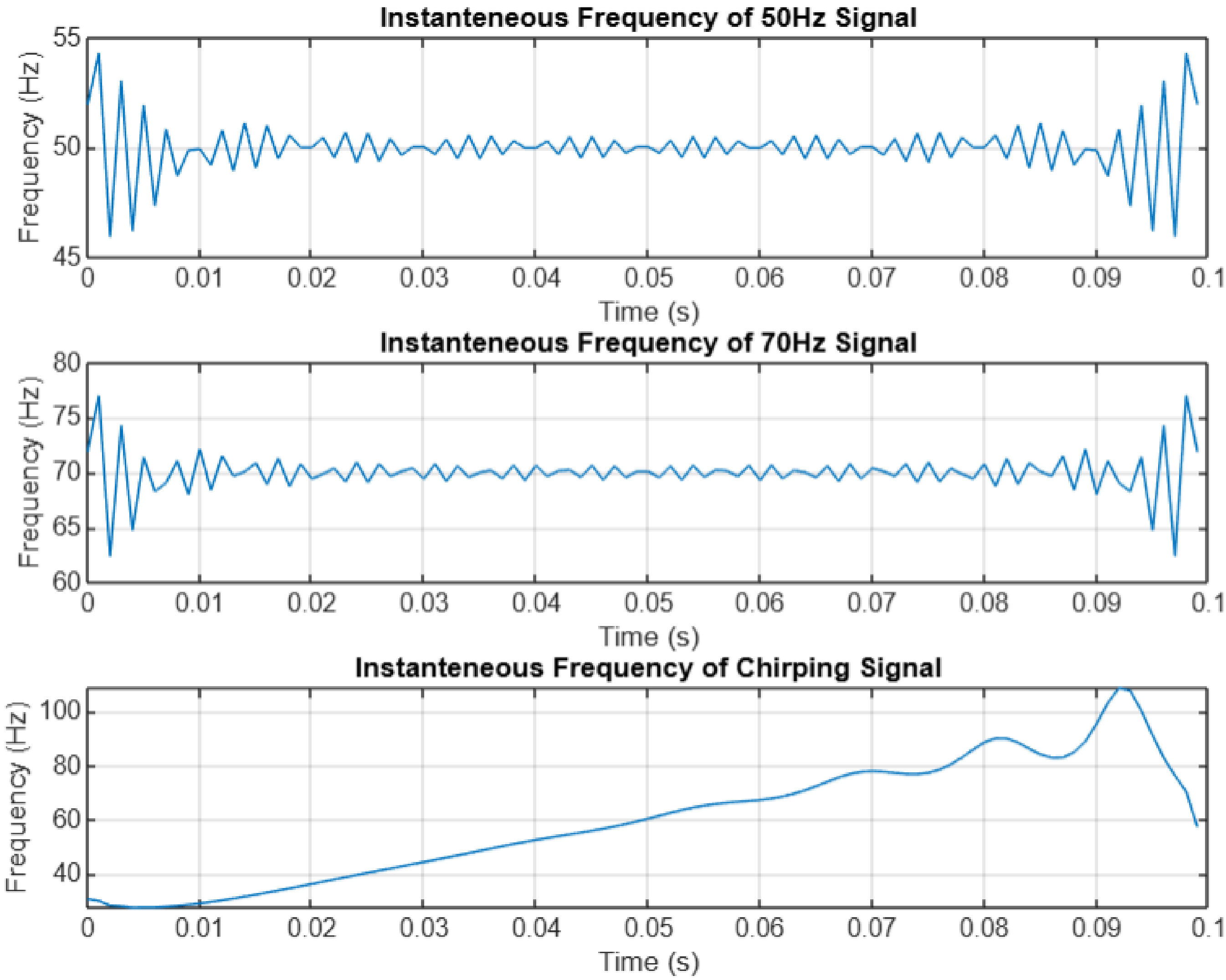


2.) Plotting Instantaneous frequency.

Answer:

Instantaneous frequency (IF) represents how the frequency of a signal changes at each moment in time. It is particularly useful for non-stationary signals where the frequency is not constant, such as **chirp signal** (where the frequency increases or decreases over time).

```
% % %    INSTANTENEOUS FREQUENCY    % % %

% Computing Instanteneous frequency frequecy using the Hilbert transform

inst_freq_50Hz = fs/(2*pi)*diff(unwrap(angle(hilbert(signal_50Hz))));
inst_freq_70Hz = fs/(2*pi)*diff(unwrap(angle(hilbert(signal_70Hz))));
inst_freq_chirp = fs/(2*pi)*diff(unwrap(angle(hilbert(chirp_signal))));


% Time vector for instanteneous frequency (adjusted due to differentiation)
t_inst = t(1:end-1);

% Plotting the Instanteneous frequencies
figure;
subplot(3, 1, 1)
plot(t_inst, inst_freq_50Hz)
title("Instanteneous Frequency of 50Hz Signal")
xlabel("Time (s)")
ylabel("Frequency (Hz)")
grid on

subplot(3, 1, 2)
plot(t_inst, inst_freq_70Hz)
title("Instanteneous Frequency of 70Hz Signal")
xlabel("Time (s)")
ylabel("Frequency (Hz)")
grid on

subplot(3, 1, 3)
plot(t_inst, inst_freq_chirp)
title("Instanteneous Frequency of Chirping Signal")
xlabel("Time (s)")
ylabel("Frequency (Hz)")
grid on
```



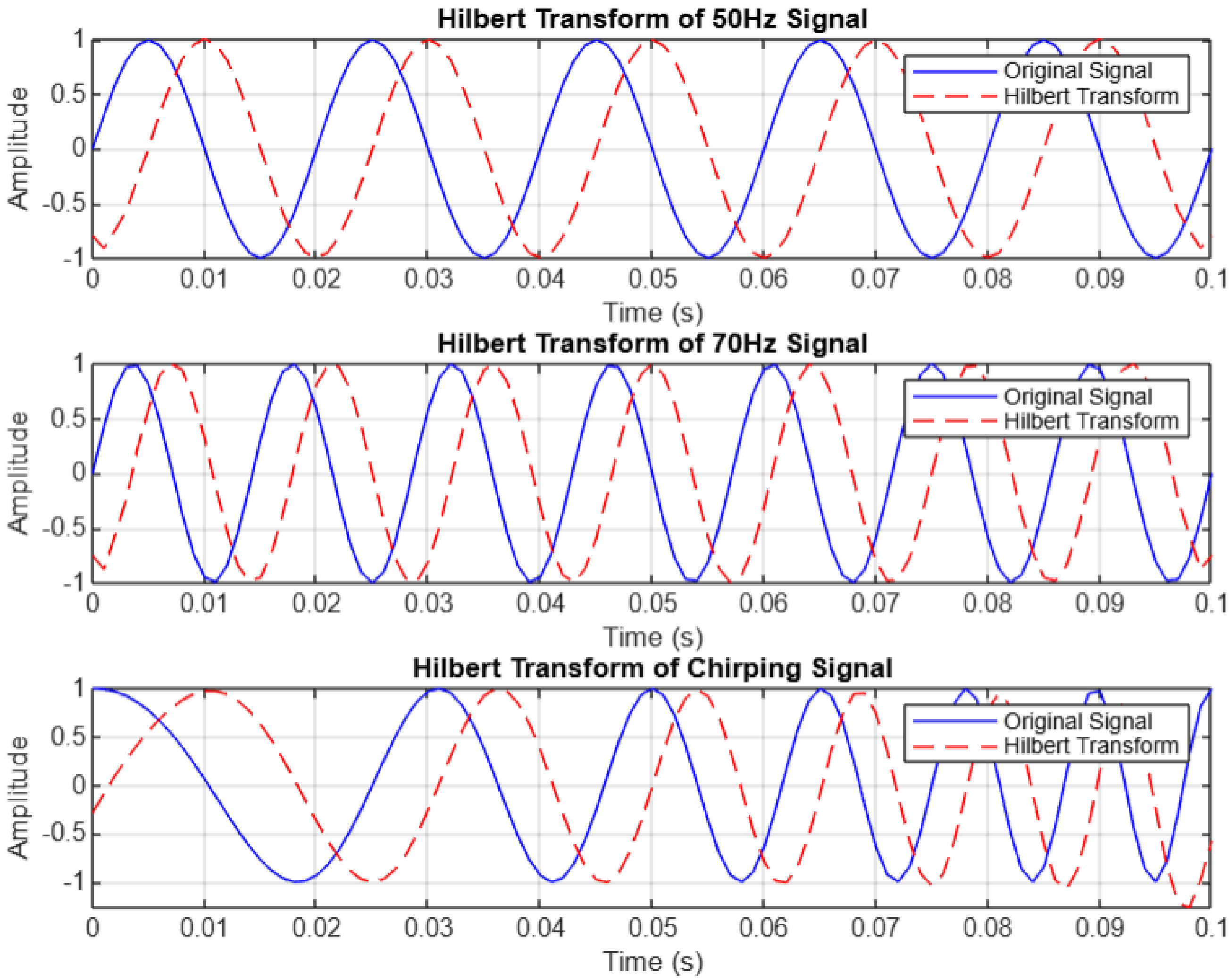
3.) Plotting Hilbert Transform.

Answer:

The **Hilbert Transform** is used to create the **analytic signal**, which consists of the original signal and its **Hilbert-transformed** counterpart. This is useful for computing the **instantaneous amplitude** and **instantaneous phase** of a signal.

```
    %%%     HILBERT TRANSFORM    %%%

% Computing Hilbert Transform

hilbert_50Hz = hilbert(signal_50Hz);
hilbert_70Hz = hilbert(signal_70Hz);
hilbert_chirp = hilbert(chirp_signal);


% Extracting Real and Imaginary parts
```

```matlab
real_50Hz = real(hilbert_50Hz);
imag_50Hz = imag(hilbert_50Hz);

real_70Hz = real(hilbert_70Hz);
imag_70Hz = imag(hilbert_70Hz);

real_chirp = real(hilbert_chirp);
imag_chirp = imag(hilbert_chirp);


% Plotting Hilbert Transform (Real and Imaginary parts)

figure;
subplot(3,1,1)
plot(t, real_50Hz, 'b', t, imag_50Hz, 'r--')
title('Hilbert Transform of 50Hz Signal')
xlabel('Time (s)')
ylabel('Amplitude')
legend('Original Signal', 'Hilbert Transform')
grid on

subplot(3,1,2)
plot(t, real_70Hz, 'b', t, imag_70Hz, 'r--')
title('Hilbert Transform of 70Hz Signal')
xlabel('Time (s)')
ylabel('Amplitude')
legend('Original Signal', 'Hilbert Transform')
grid on

subplot(3,1,3)
plot(t, real_chirp, 'b', t, imag_chirp, 'r--')
title('Hilbert Transform of Chirping Signal')
xlabel('Time (s)')
ylabel('Amplitude')
legend('Original Signal', 'Hilbert Transform')
grid on
```



4.) Plotting Hilbert Envelope.

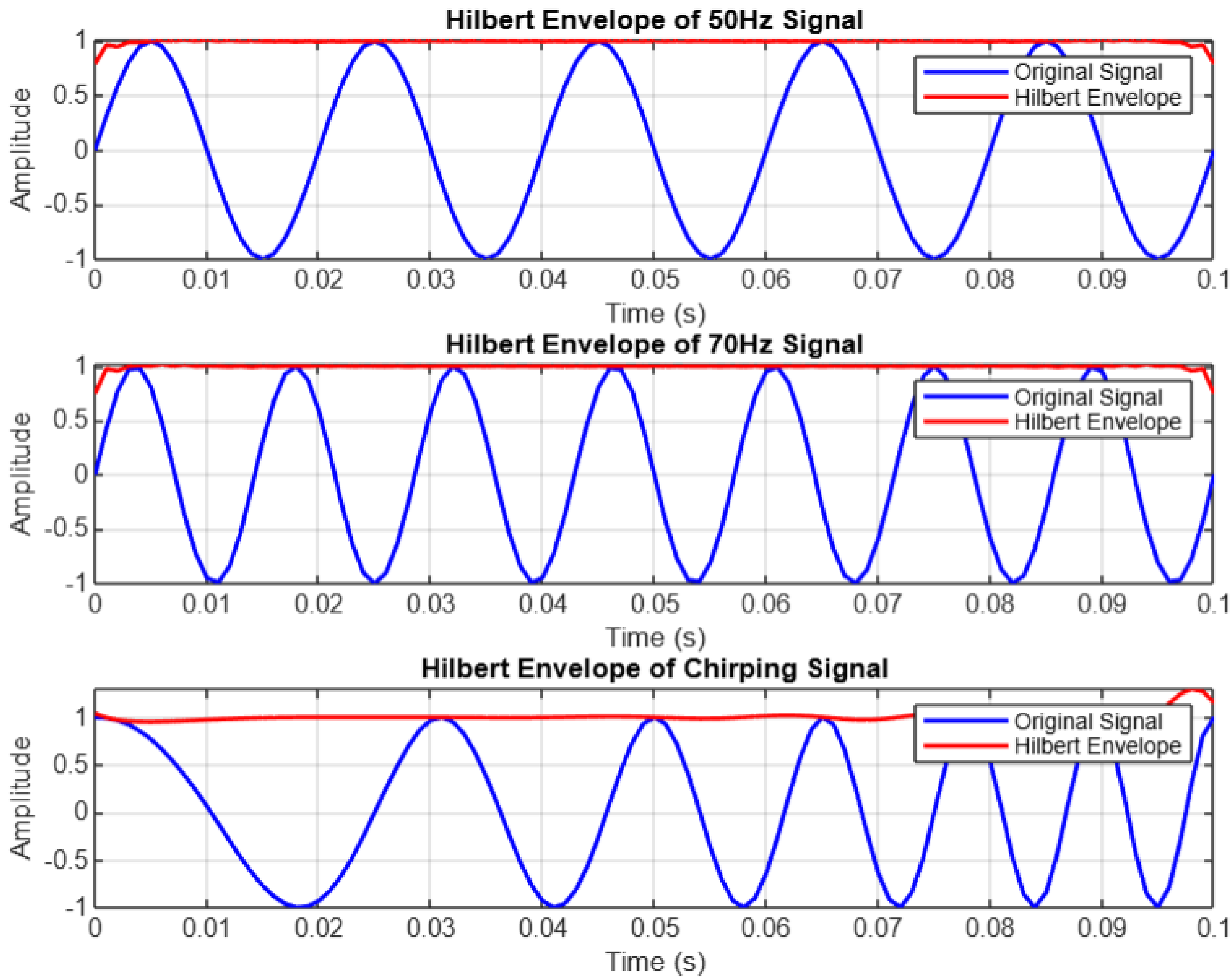
Answer:

The **Hilbert envelope** is the **instantaneous amplitude** of a signal. It is useful in: -

- ⇨ Speech and biomedical signal processing (e.g., ECG, EEG)
- ⇨ Identifying amplitude variations in signals
- ⇨ Extracting features from audio and speech signals
- ⇨ **Magnitude determines the contrast:** The magnitude affects the contrast and intensity of the reconstructed image, but does not significantly alter the spatial arrangement of features.

Code:

```matlab
% 202411012
    % % %    HILBERT  ENVELOPE  % % %

% Computing Hilbert Envelope

envelope_50Hz = abs(hilbert_50Hz);
envelope_70Hz = abs(hilbert_70Hz);
envelope_chirp = abs(hilbert_chirp);


% Plot Signals and Envelopes
figure;
subplot(3,1,1)
plot(t, signal_50Hz, 'b', t, envelope_50Hz, 'r', 'LineWidth', 1.5)
title('Hilbert Envelope of 50Hz Signal')
xlabel('Time (s)')
ylabel('Amplitude')
legend('Original Signal', 'Hilbert Envelope')
grid on

subplot(3,1,2)
plot(t, signal_70Hz, 'b', t, envelope_70Hz, 'r', 'LineWidth', 1.5)
title('Hilbert Envelope of 70Hz Signal')
xlabel('Time (s)')
ylabel('Amplitude')
legend('Original Signal', 'Hilbert Envelope')
grid on

subplot(3,1,3)
plot(t, chirp_signal, 'b', t, envelope_chirp, 'r', 'LineWidth', 1.5)
title('Hilbert Envelope of Chirping Signal')
xlabel('Time (s)')
ylabel('Amplitude')
legend('Original Signal', 'Hilbert Envelope')
grid on
```


Hilbert Envelope of 50Hz Signal
Hilbert Envelope of 70Hz Signal
Hilbert Envelope of Chirping Signal
Amplitude
Time (s)
Original Signal
Hilbert Envelope
1
0.5
0
-0.5
-1
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1

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