PRACTICAL - 4

TO SUDY AND OBSERVE THE EFFECT OF DOPPLER SPREAD AND DELAY SPREAD FOR FAST FADING AND SLOW FADING CHANNEL AND CALCULATE THE COHERENT BANDWIDTH IN MATLAB

- 1. COHERENCE TIME AND DOPPLER SPREAD

- 2. COHERENCE FREQUENCY AND DELAY SPREAD

DOPPLER SPREAD:

- Doppler shift is the random changes in a channel introduced as a result of a mobile user's mobility.
- Doppler spread has the effect of shifting or spreading the frequency components of a signal
- Types of fading on the basis of doppler spread are fast fading and slow fading.
  • Fast fading : Channel impulse response changes rapidly within the symbol duration.
  • Slow fading : Channel impulse response changes at a rate much slower than the transmitted symbol bandwidth.
  • Doppler spread is expressed in the following formula. As mentioned, doppler spread is defined as maximum doppler shift (fm).

Doppler spread:-

$$f_m = \frac{v}{\lambda}$$

v = velocity of moving vehicle

λ = wavelength = c/f

f = frequency of carrier

c = speed of electromagnetic wave in free space (3×10^8 m/s)

COHERENCE TIME:

- The coherence time of the channel is the inverse of the Doppler spread.
  - It is the measure of the speed at which channel characteristics change.
- The coherence time is the time over which a propagating wave may be considered coherent. In other words, it is the time interval within which its phase is, on average, predictable.

Coherence time :-

$$T_c \approx \frac{1}{2\pi f_m}$$

where:

Maximum doppler spread,

$$f_m = \frac{v}{\lambda}$$

DELAY SPREAD:

As we know that radio frequency signal takes different path to reach the destination due to multiple paths. This multiple paths cause reflection, refraction and scattering of radio signal. Hence when the signal is transmitted from one place to the other, multiple copies of the signal is received with different amplitudes and different delays (leads to different time of arrival) at the receiver

For example, if an impulse is transmitted then it will be no longer a impulse when it is received at the other end, but it will become a pulse with spreading effect. The effect which makes this spreading of signal is known as Delay spread.

To measure performance of a wireless system different scenarios from low to medium to high delay spreads are considered for test purpose. Delay spread helps determine coherence bandwidth and coherence time of a wireless system.

- ***Delay spread*** is a measure of the multipath profile of a mobile communications channel. It is generally defined as the difference between the time of arrival of the earliest component (e.g., the line-of-sight wave if there exists) and the time of arrival of the latest multipath component.
- *Coherence bandwidth* B_c is a statistical measure of the range of frequencies over which the channel can be considered flat (i.e., it passes all spectral components with approximately equal gain and linear phase). All frequency components of the transmitted signal within the coherence bandwidth will fade simultaneously. The coherence bandwidth is inversely proportional to the delay spread, and we thus have the following:

$$B_c = \frac{1}{\sigma_\tau}$$

- In doppler spread, how fast the transfer function of the time-varying channel changes with time for a fixed frequency is to be studied. Doppler spread and the coherence time are used for the same. It is due to the different Doppler shift frequencies associated with the multiple propagation paths when there is relative motion between the transmitter and the receiver

- In delay spread, how fast the transfer function of the time-varying channel changes with frequency at a particular time instant is to be studied. It happens because different propagation paths have different time delays.

COHERENCE TIME AND DOPPLER SPREAD

Let the time-varying propagation delay and attenuation of the particular path j be represented respectively as follows:

$$\tau_j(t) = \tau_0 + \tau_j^{'} t \tag{1.5}$$

$$\beta_j(t) = \beta_j \tag{1.6}$$

$$\Rightarrow H(f,t) = \sum_{j=1}^{j=J} \beta_j e^{-i*2*\pi*f*(\tau_0+\tau_j^{'} t)} \tag{1.7}$$

$$\Rightarrow H(f,t) = \sum_{j=1}^{j=J} \beta_j e^{-i*2*\pi*f*\tau_0} e^{-i*2*\pi*f*\tau_j^{'} t} \tag{1.8}$$

Let $D_j = -f * \tau_j^{'}$, and rewriting (1.8), we get

$$H(f,t) = \sum_{j=1}^{j=J} \beta_j e^{-i*2*\pi*f*\tau_0} e^{i*2*\pi*D_j t} \tag{1.9}$$

$$H(f, t) = \sum_{j=1}^{j=J} \beta_j e^{-i*2*\pi*f*\tau_0} e^{i*2*\pi*D_j t} \tag{1.9}$$

The response to the eigenfunction $e^{i*2*pi*f_0 t}$ is given as follows:

$$H(f_0, t) = \sum_{j=1}^{j=J} \beta_j e^{-i*2*\pi*f_0*\tau_0} e^{i*2*\pi*D_j t} e^{i*2*pi*f_0 t} \tag{1.10}$$

$$\Rightarrow y_e(t) = \sum_{j=1}^{j=J} \beta_j e^{-i*2*\pi*f_0*\tau_0} e^{i*2*\pi*(D_j+f_0)t} \tag{1.11}$$

From (1.10), it is observed that there is a shift in the frequency in every path of the transmission. For instance, the shift in the frequency in the jth path is given as D_j+f_0. This is called Doppler shift. Let $\arg_j \min(D_j) = D_{\min}$ and $\arg_j(\max(D_j)) = D_{\max}$. The range of frequencies described as $D = D_{\max} - D_{\min}$ is known as Doppler spread. The response of the channel to the signal $\cos(2 * \pi * f_o * t)$ is given as follows:

$$y(t) = \Re\left(\sum_{j=1}^{j=J} \beta_j e^{-i*2*\pi*f_0*\tau_0} e^{i*2*\pi*(D_j+f_0)t}\right) \tag{1.12}$$

Let the value of the transfer function of the time-varying (multi-path) channel at frequency $f = f_0$ in polar form be represented as $|H(f_0, t)|e^{-j\angle(H(f_0,t))}$. The response to the signal $\cos(2 * pi * f_0 * t)$ is obtained as $y(t) = |H(f_0, t)| \cos(2 * pi * f_0 * t - \angle(H(f_0, t)))$. Assuming that the phase response $\angle(H(f_0, t))$ is slowly varying with time. Ideally we expect $|H(f_o, t)|$ (envelope) to be the flat response. But because of the presence of the Doppler spread, $|H(f_o, t)|$ varies with time. We would like to have the rate at which $|H(f_o, t)|$ is changing with time should be minimal.

Case study :

- Consider the signal $\cos(2\pi f_o t)$ $f_o = 1$ MHz. Also let the rate at which the delay (τ_j) is changing with time be randomly chosen as TAU_J = [0.62 1.84 0.86 0.37].
- Hence the corresponding Doppler shift for the frequency f_o in the corresponding paths is obtained as

  DJ = $-f_o$*TAUJ and the actual shift in the frequency is given as fshift = |DJ + f_o| = [0.38 0.84 0.14 0.63]
- Attenuation in individual paths, BETA = [0.23 0.17 0.23 0.44]
- Thus the received signal is represented as $\sum_{j=1}^{4} BETA(j)\cos(2*\pi*fshift(j)*t)$
- The received signal and the corresponding spectrum are given as shown in the next slide

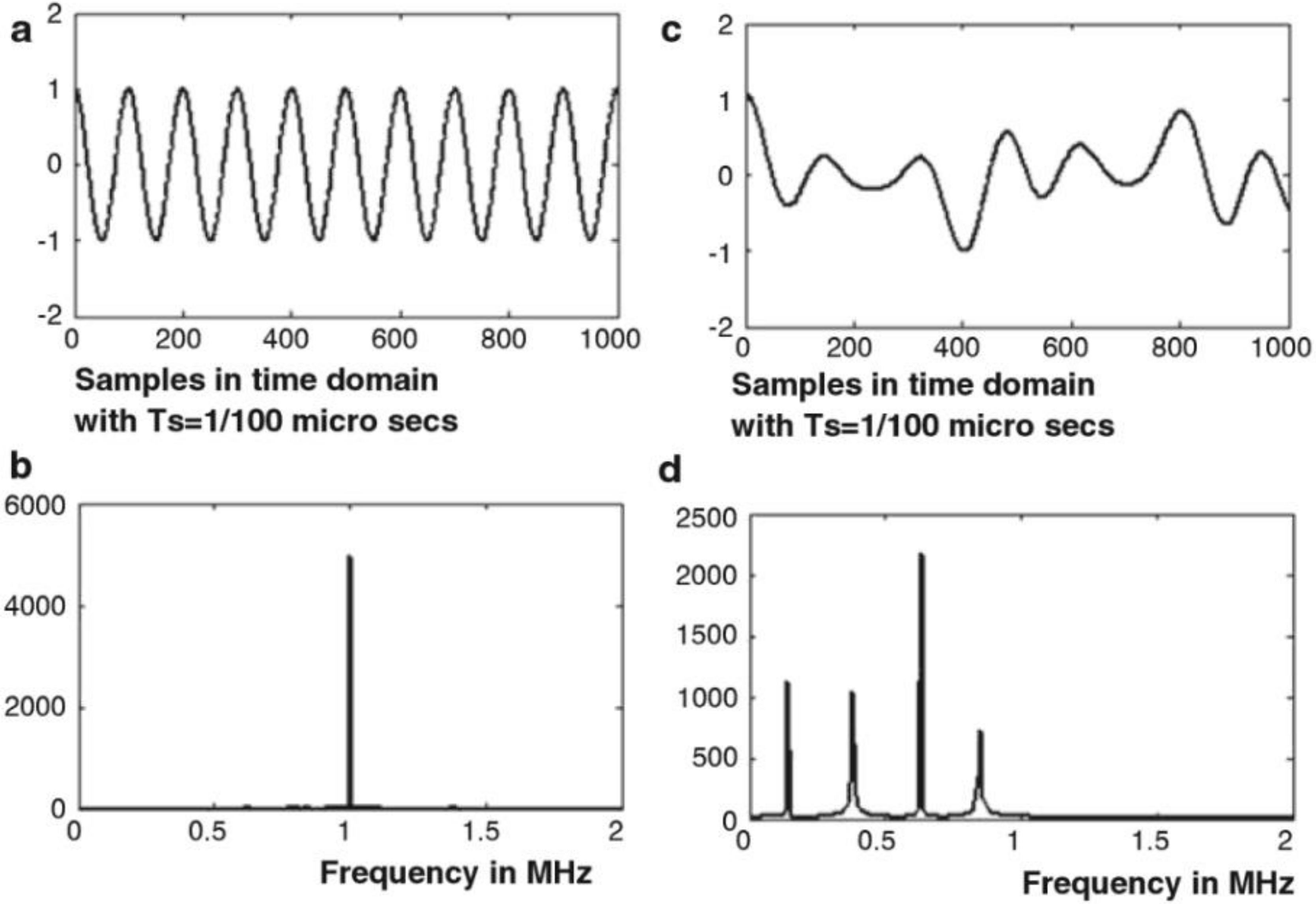


Figure: (a) Transmitted signal, (b) corresponding spectrum of the transmitted signal, (c) received signal after subjected to multi-path (d) corresponding spectrum of the received signal

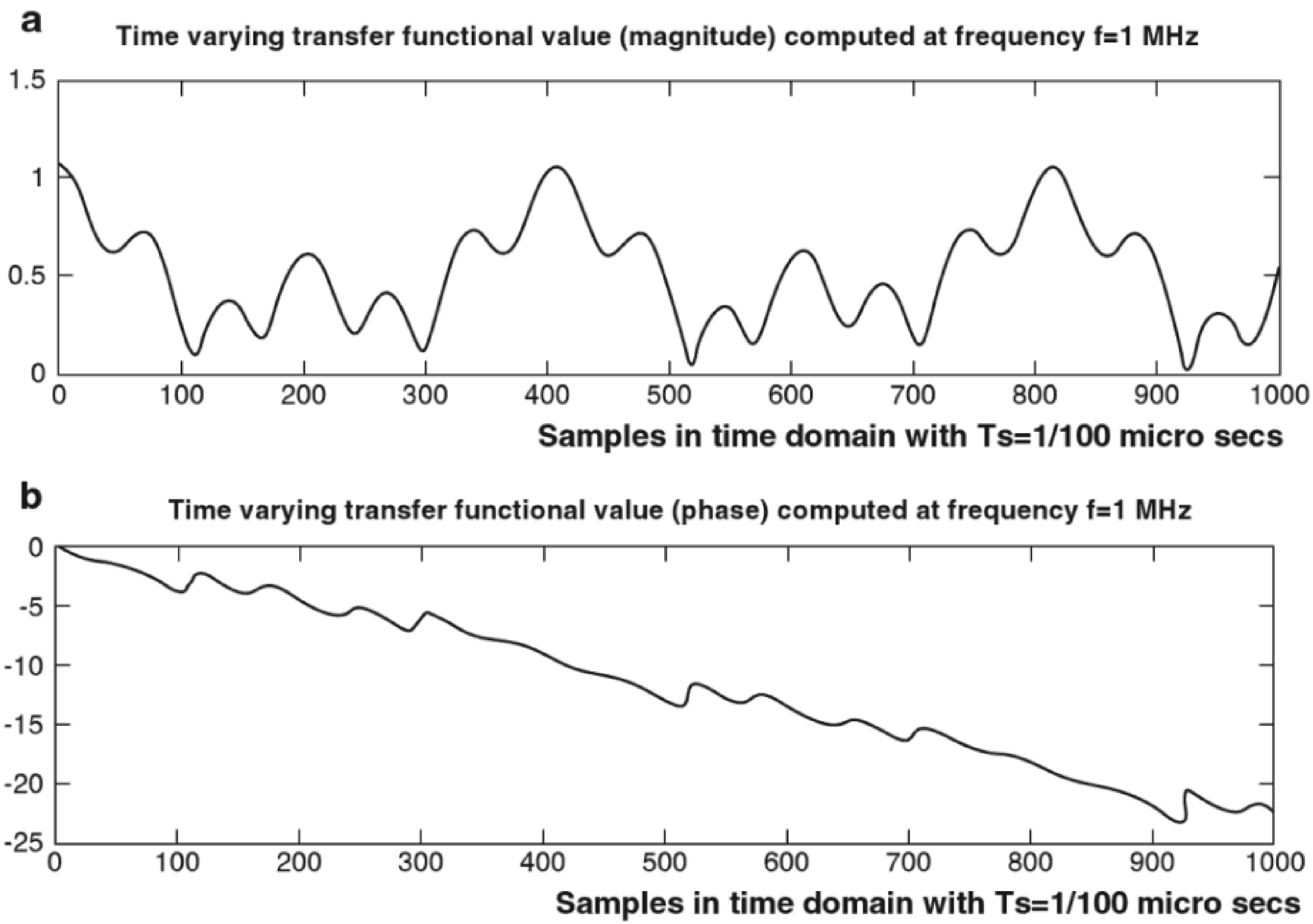


Figure: Illustration of the fast fading channel characteristics

Slow Fading

1. $TAUJ = [0.0042\ 0.0098\ 0.0030\ 0.0070]$.
2. $fshift = |DJ + f_0| = [0.9958\ 0.9902\ 0.9970\ 0.9930]$.
3. $BETA = [0.2691\ 0.4228\ 0.5479\ 0.9427]$.
4. The bandwidth of the received signal corresponding to the single tone transmitted signal (f_0 =1 MHz) is given as 6800 Hz.
5. The bandwidth of the spectrum in Fig. 1.8d is identified as the Doppler spread.
6. The envelope of the wave in Fig. 1.8c is identical with Fig. 1.9a.
7. The coherence time is computed as $t_{\text{coh}} = \frac{1}{2D} = 73\,\mu\text{s}$ and is illustrated in Fig. 1.10. It is the zoomed version of Fig. 1.9a.

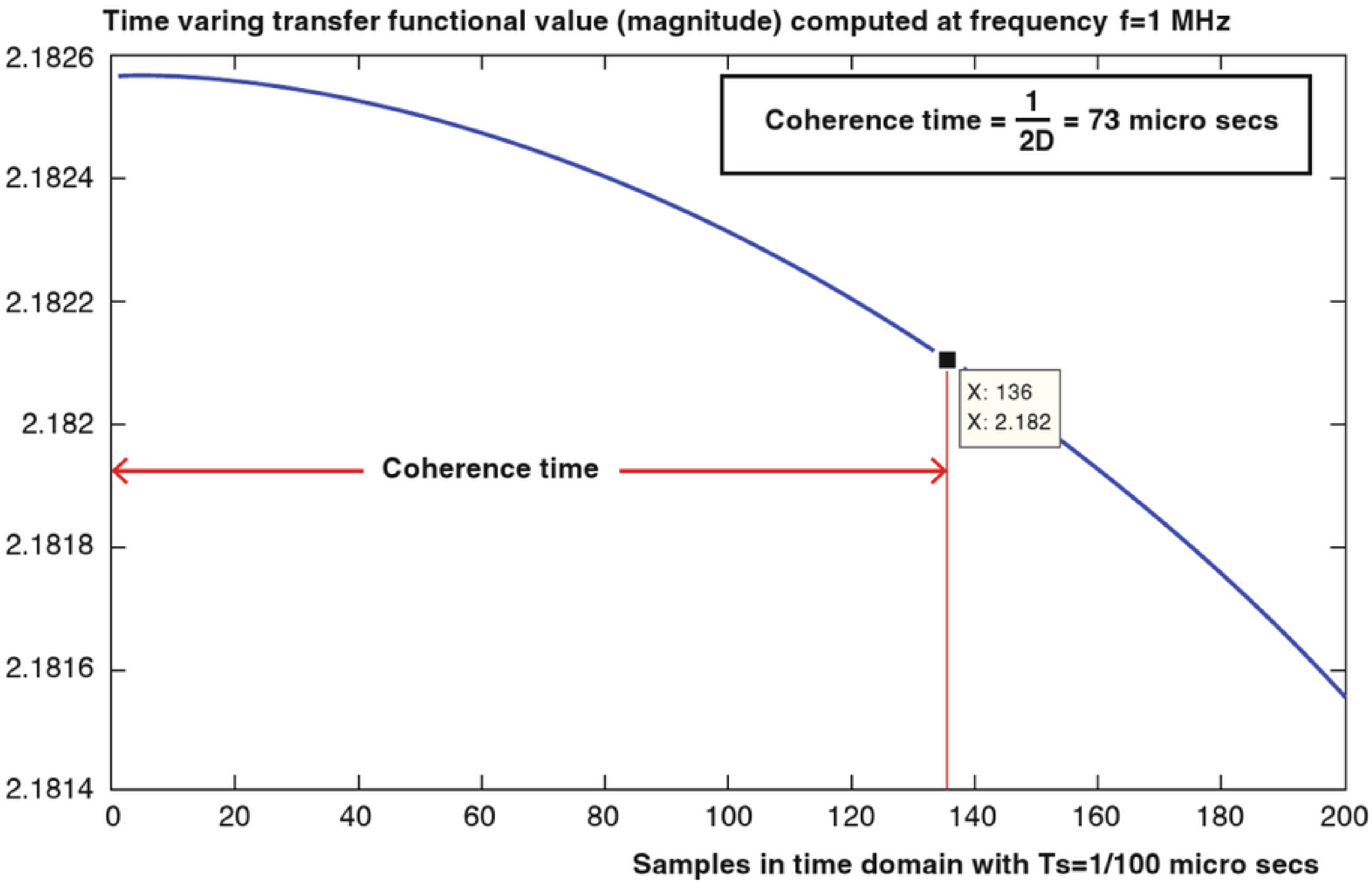


Figure: Illustration of the computation of the coherence time using Doppler spread (D)

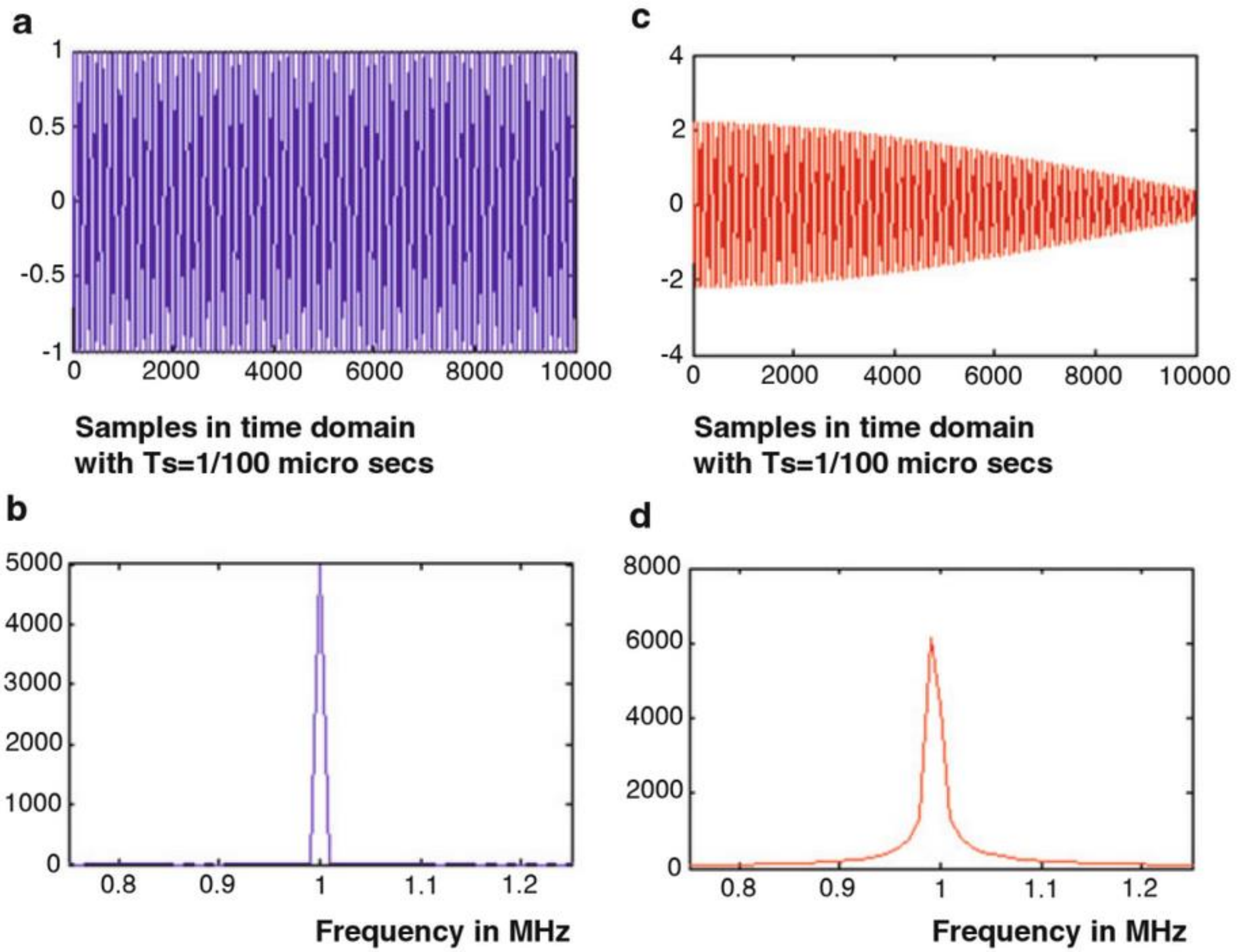
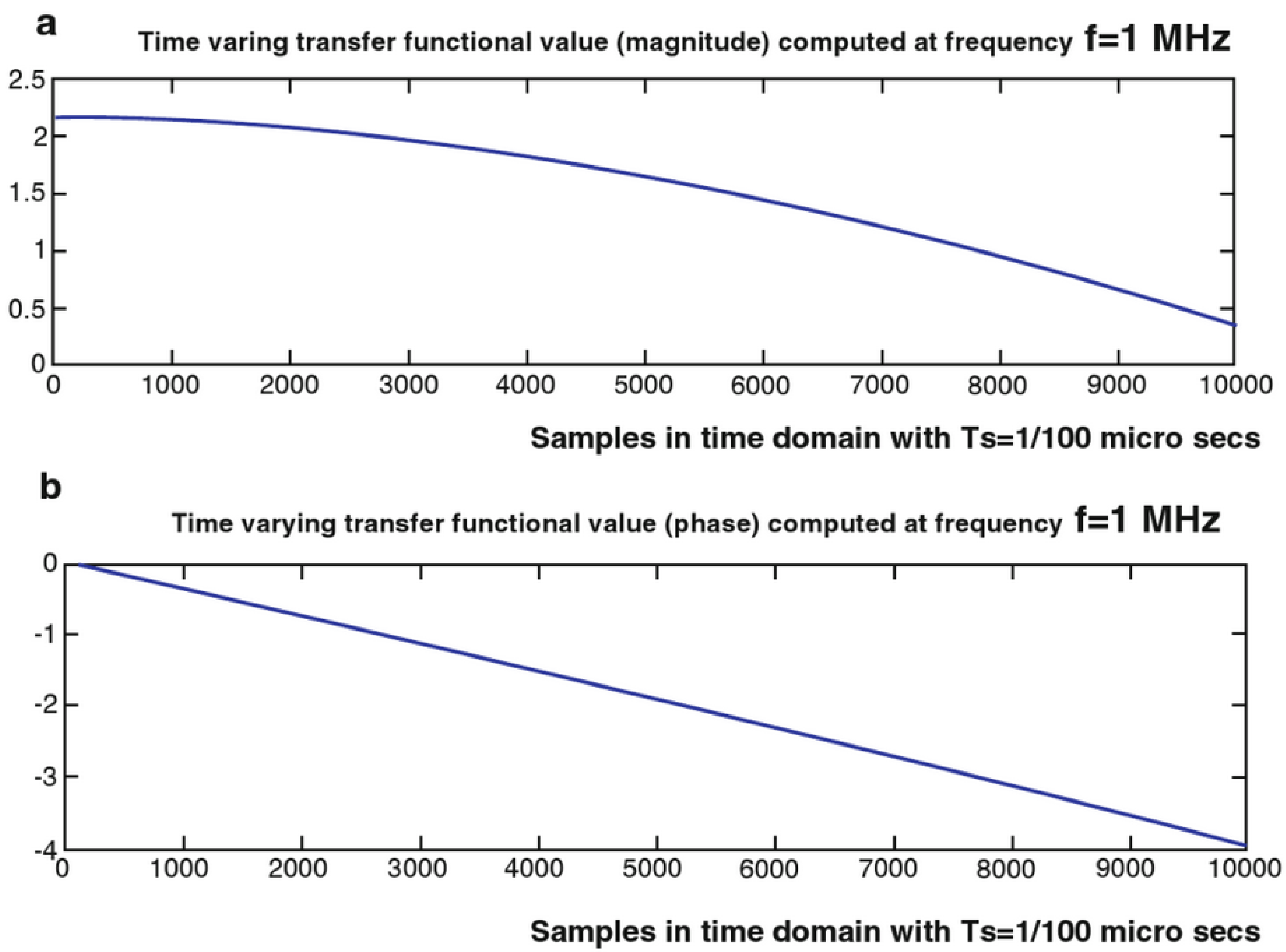


Figure: (a) Transmitted signal, (b) corresponding spectrum of the transmitted signal, (c) received signal after subjected to multi-path slow fading and (d) corresponding spectrum of the received signal

COHERENCE FREQUENCY AND DELAY SPREAD



Case Study :

The variation of the transfer function with frequency at a particular time instant $t_0 = 1\ \mu s$ is used.

1. TAUJ = [0.9143 -0.0292 0.6006 -0.7162]
2. BETA = [0.9575 0.9649 0.1576 0.9706]
3. Delay spread = L = 1.6306 and the coherence frequency is computed as

$$f_{coh} = \frac{1}{2L} = 306\ KHz$$

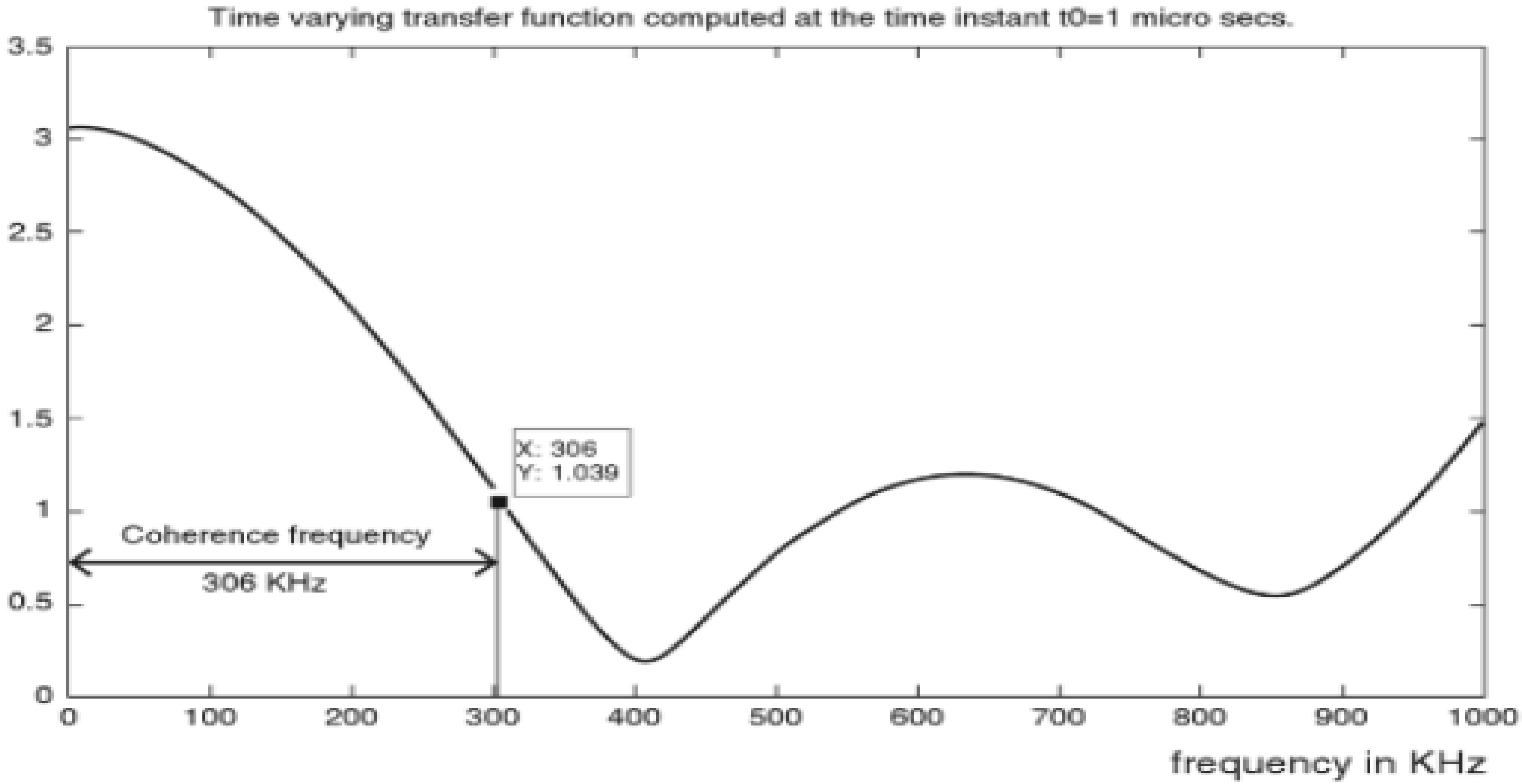
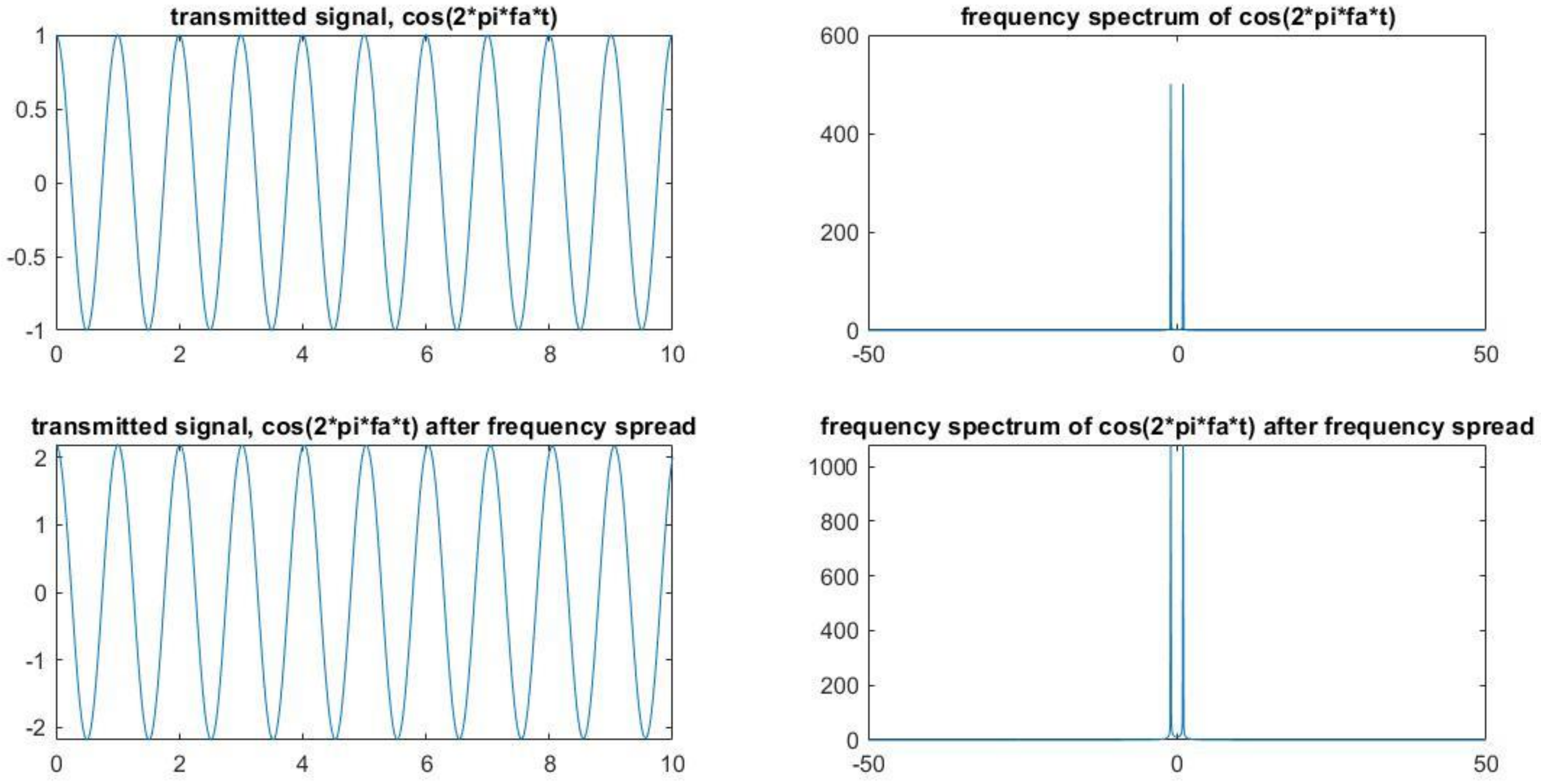
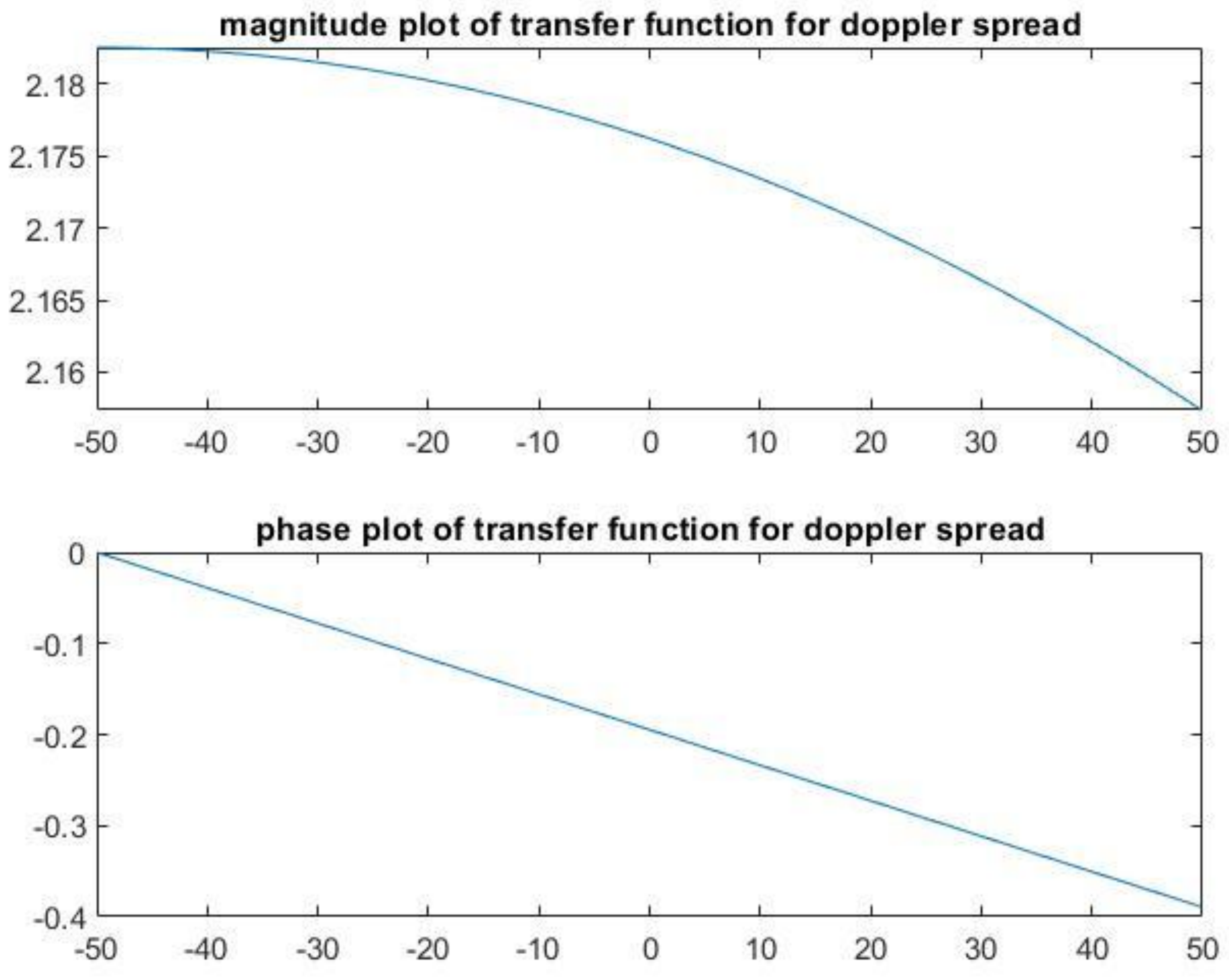


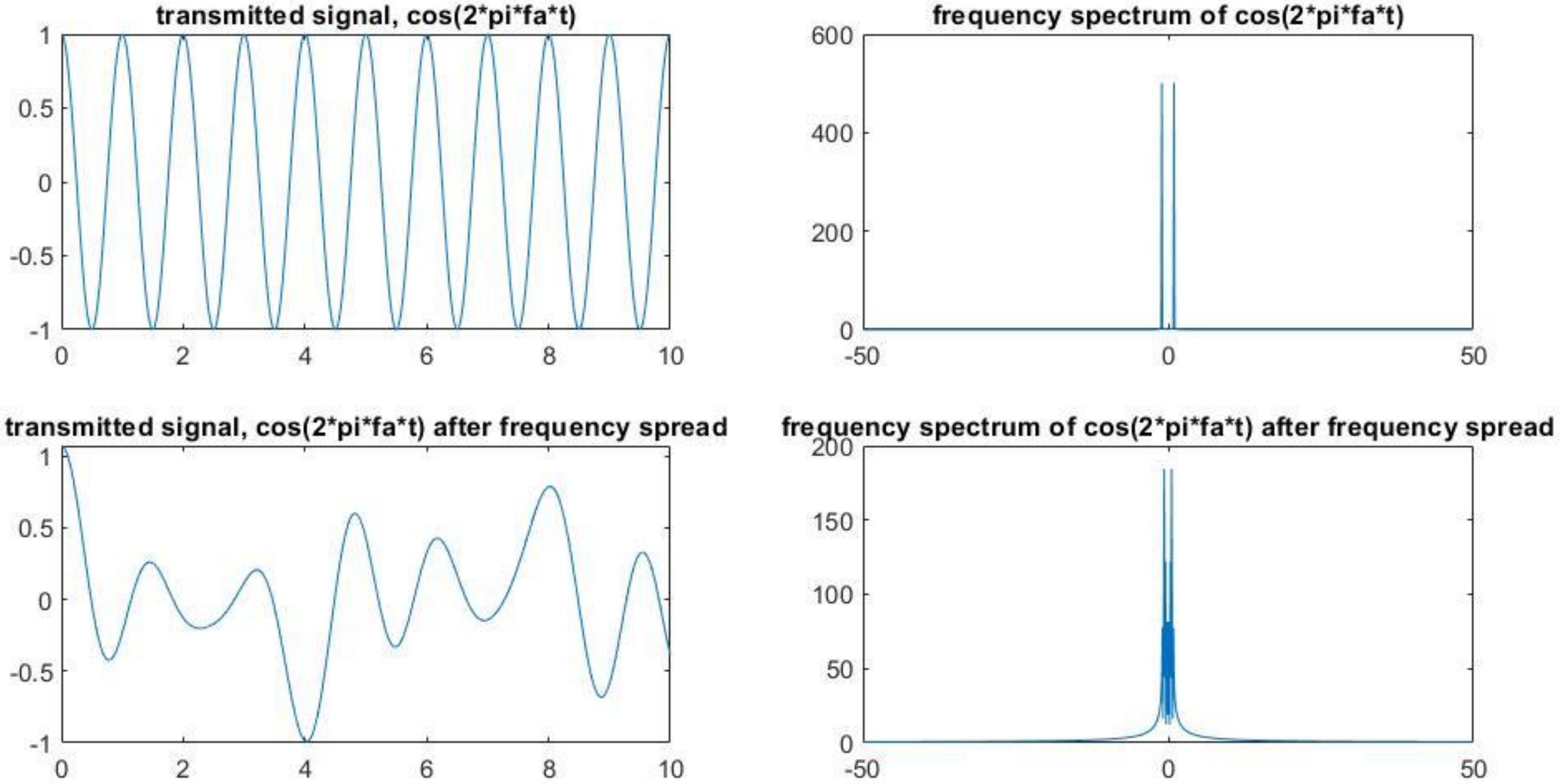
Fig. 1.11 Illustration of the computation of the coherence frequency using delay spread (L)

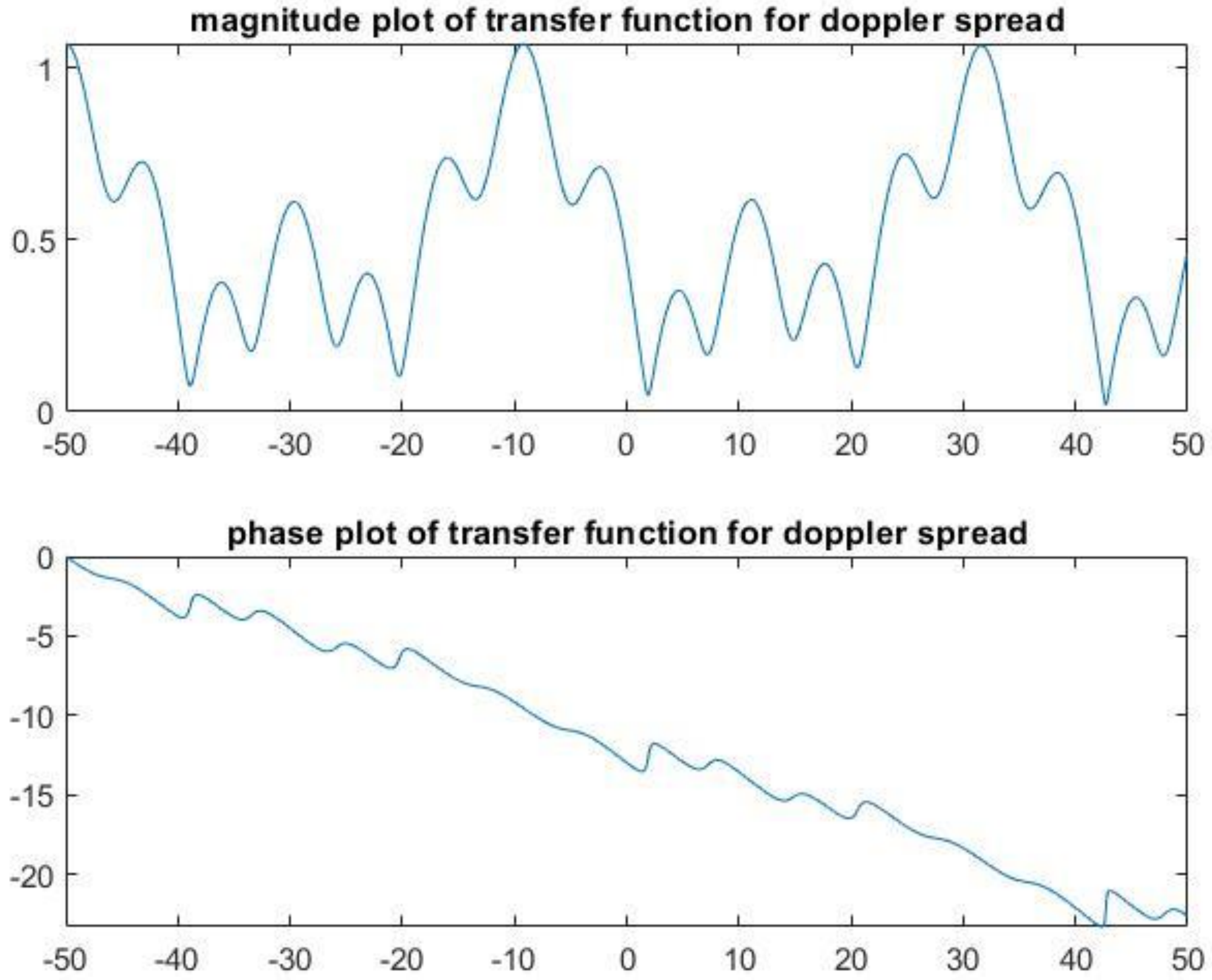
SLOW FADING MODEL




magnitude plot of transfer function for doppler spread
2.18
2.175
2.17
2.165
2.16
-50
-40
-30
-20
-10
0
10
20
30
40
50
phase plot of transfer function for doppler spread
0
-0.1
-0.2
-0.3
-0.4
-50
-40
-30
-20
-10
0
10
20
30
40
50

FAST FADING MODEL




magnitude plot of transfer function for doppler spread
1
0.5
0
-50
-40
-30
-20
-10
0
10
20
30
40
50
phase plot of transfer function for doppler spread
0
-5
-10
-15
-20
-50
-40
-30
-20
-10
0
10
20
30
40
50