Chapter 5

System Performance

5.1. System Parameters

The system has been evaluated using the following LTE system parameters.

BW	20 MHz
Cyclic prefix	Normal cyclic prefix
Number of Rx antennas	1
Sampling frequency	30.72 MHz

Table 5.1 System Parameters used in performance results.

The simulations are evaluated using EPA model EVA model and ETU model as shown in [6] with signal to noise ratio (SNR) from -6:16 dB.

EPA model is a propagation channel model based on the International Telecommunication Union (ITU) Pedestrian A model [21], extended to a wider bandwidth of 20 MHz. The pedestrian channel model represents a UE speed of 3 km/h [22].

EVA model is a propagation channel model based on the International Telecommunication Union (ITU) Vehicular A model [21], extended to a wider bandwidth of 20 MHz. The vehicular channel model represents UE speeds of 30, 120 km/h and higher [22].

The International Telecommunications Union (ITU) developed set of models that is available only as a tapped-delay line implementation [ITU 1997]. It specifies three environments: indoor, pedestrian (including outdoor to indoor), and vehicular (with high BS antennas). For each of those environments, two channels are defined: channel A (low delay spread case) and channel B (high delay spread).

ETU model is a propagation channel model based on the GSM Typical Urban model [23], extended to a wider bandwidth of 20 MHz. It models a scattering environment which is considered to be typical in a urban area [22].

Here we will compare our proposed frequency domain method "with various values for M" with the conventional time domain method explained in chapter 4.

We also examine the neighboring cell effect on the two techniques.

Although the frequency offset effect is not in our scope in the proposed method, we simulated the two techniques with different values of frequency offset.

Finally we compare the effect of the bandwidth on the proposed method.

5.2. Performance Results

5.2.1. Frequency Domain Method versus Conventional Time Domain Method

In figures 5.1, 5.2 and 5.3 we compare the probability of false alarms from the Frequency domain based method with different window step sizes M and correlation in time domain, that is correlating N symbols from the received frame with replicas of the three primary synchronization signals in time domain and repeating this step every N symbols with window step equals one.

A false alarm occurs when the estimated N_{ID}^{cell} and the N_{ID}^{cell} of the transmitted signal are not equal or the error in the estimated sub-frame start is greater than a certain number of samples. Here we assume that the error is greater than the cyclic prefix length per OFDM symbol, which is in our case 144 samples.

As shown in figures 5.1, 5.2 and 5.3 the probability of false alarm decreases as the SNR increases. In high SNRs, the performance of the frequency domain based method approaches the conventional time domain method.

We can also see the improvement in the performance as the window step size M decreases. The performance improvement saturates after M=512, at which performance does not improve and the complexity increases as will be shown.

FD method is the frequency domain based method and TD method is the time domain method.

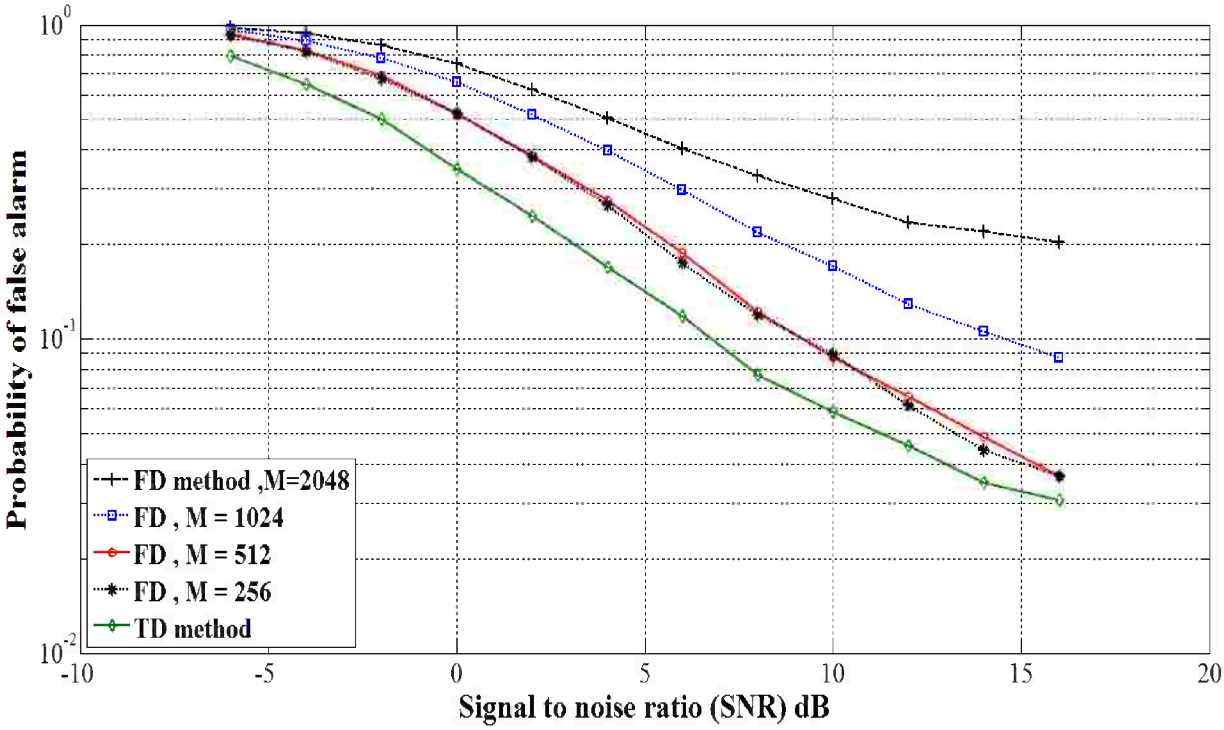

Figure 5.1 Probability of false alarms versus signal to noise ratios in (EPA) channel for the Frequency domain based method with different window step sizes M and for time domain based method.

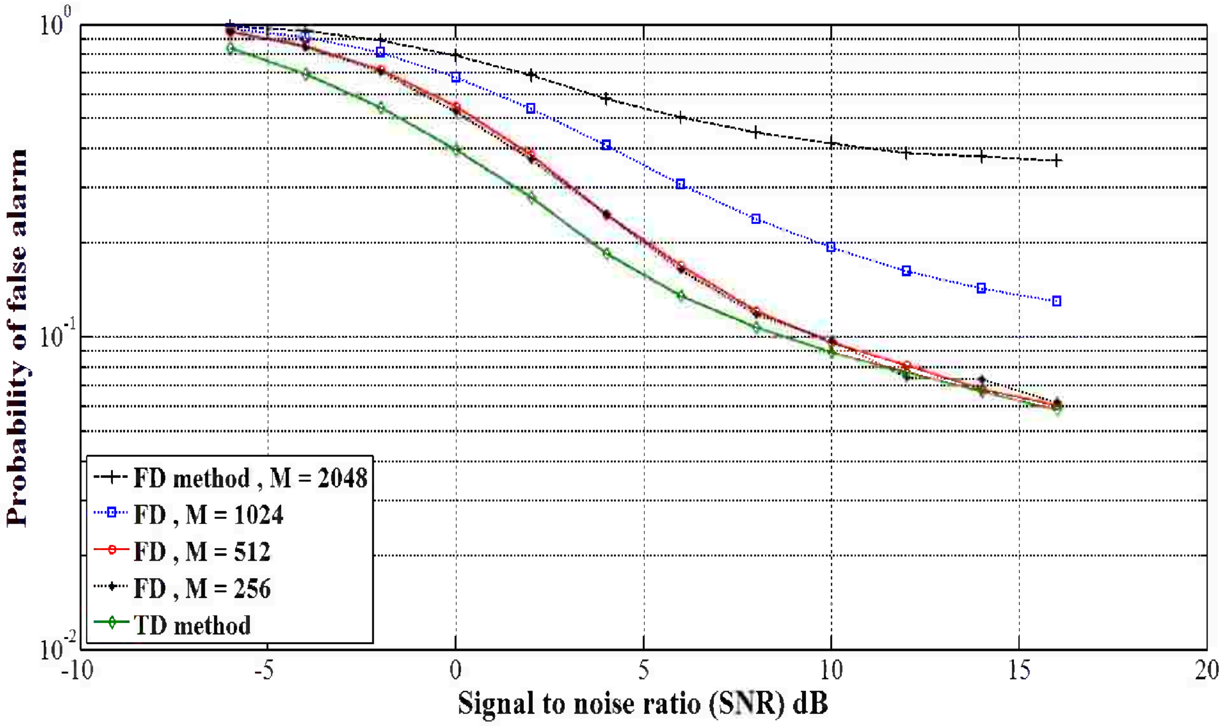

Figure 5.2 Probability of false alarms versus signal to noise ratios in (EVA) channel for the Frequency domain based method with different window step sizes M and for time domain based method.

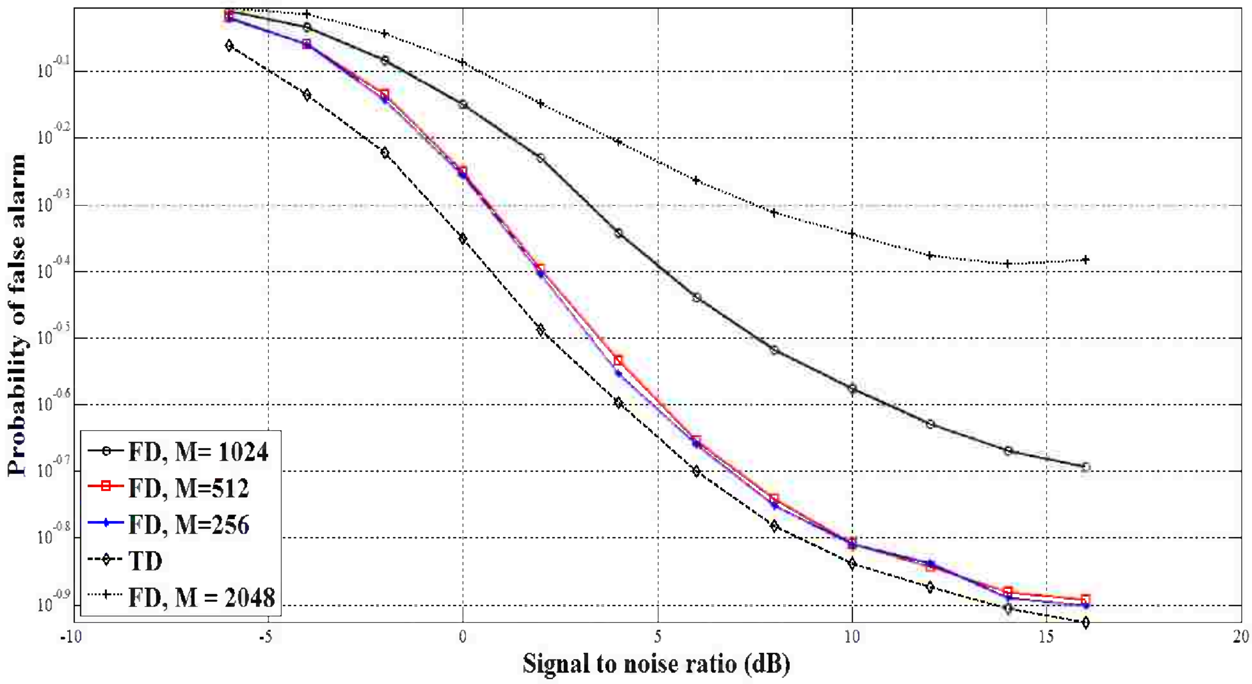

Figure 5.3 Probability of false alarms versus signal to noise ratios in (ETU) channel for the Frequency domain based method with different window step sizes M and for time domain based method.

5.2.2. Effect of Inter Cell Interference on Frequency Domain Based Method

In Figures 5.4, 5.5 and 5.6 we have simulated the effect of neighbor cells on Frequency domain based method and calculated the probability of false alarms depending on two concepts. The first one is like the simulations in Figure 5.1 (the estimated N_{ID}^{cell} and the N_{ID}^{cell} of the transmitted signal are not equal or the error in the estimated sub-frame start is greater than the cyclic prefix length per OFDM symbol) and the other one is that a successful detection if the estimated N_{ID}^{cell} equals any of N_{ID}^{cell}s of the two cells, which means that the UE has established a successful connection with any of the two cells, other than that a false alarm occurs. We calculate the sub-frame start error also as mentioned before (error in the estimated sub-frame start is less the cyclic prefix length “144 samples”).

As shown in Figures 5.4, 5.5 and 5.6, as the difference in power between the targeting cell and the neighboring cell in (dB) increases , (which means that the UE moves from the edge of the cell to the center) the performance improves till it is almost like the single cell performance at power difference equals 21 dB.

Another note is that in low power difference (high interference from the neighboring cell) the difference in performance of the two concepts mentioned above is large.

This difference in performance decreases as interference from neighboring cell decreases till it almost disappears which means that the neighboring cell interference effect has almost been eliminated by the Frequency domain based method.

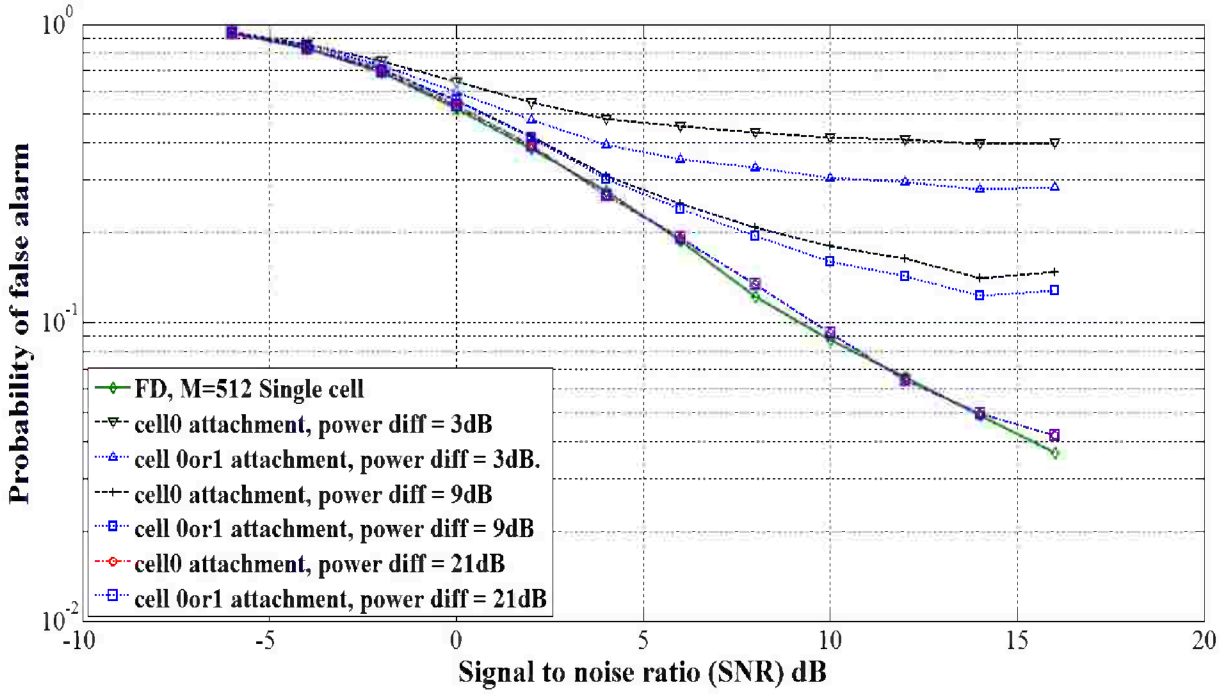

Figure 5.4 Probability of false alarms versus signal to noise ratios in (EPA) channel for neighbor cell effect on Frequency domain based method.

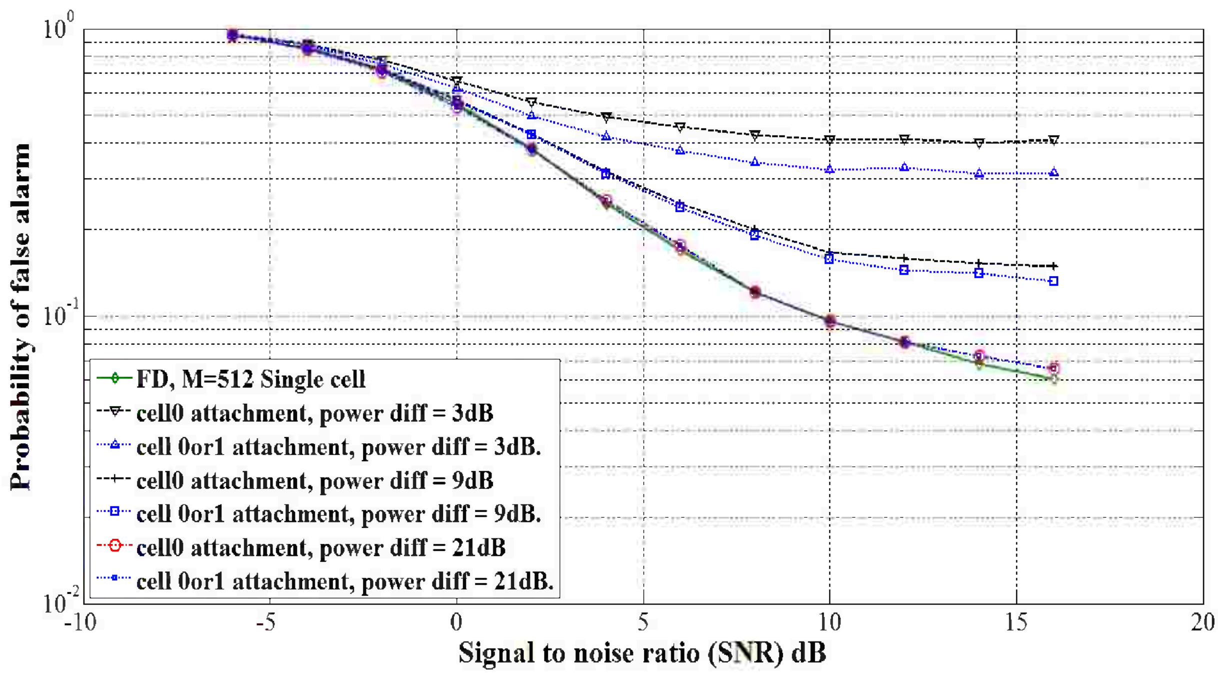

Figure 5.5 Probability of false alarms versus signal to noise ratios in (EVA) channel for neighbor cell effect on Frequency domain based method.

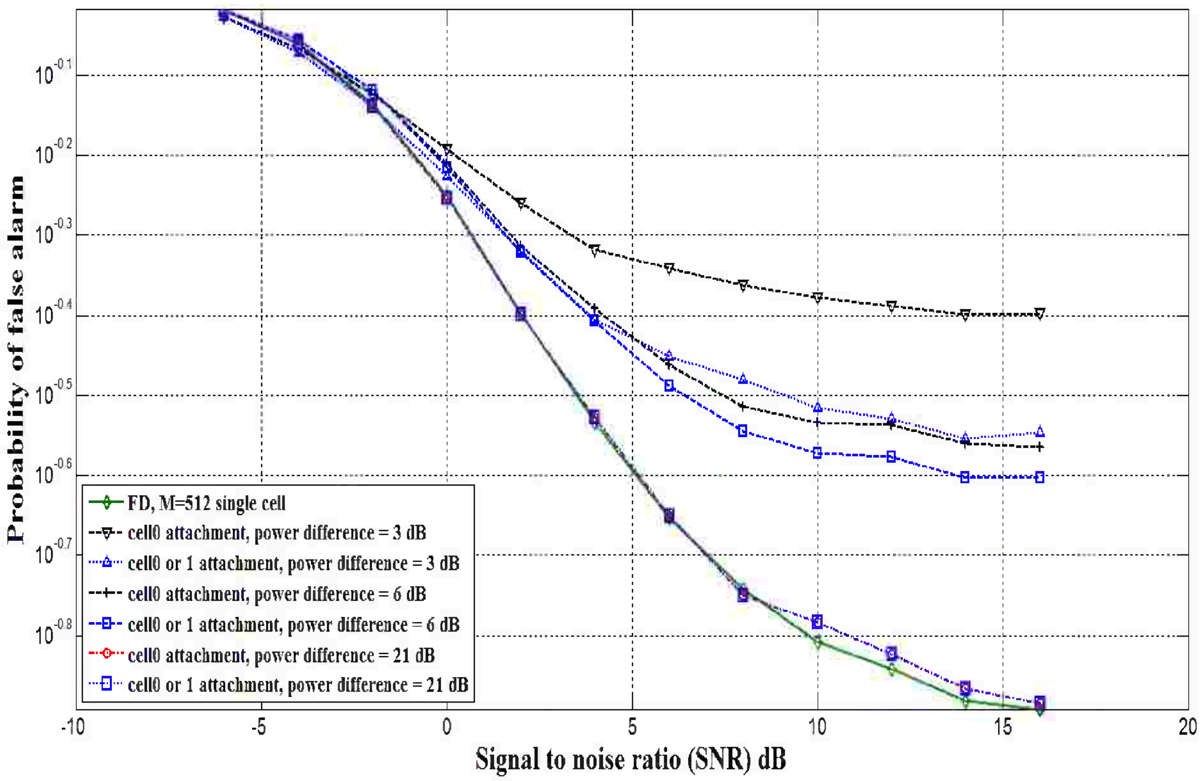

Figure 5.6 Probability of false alarms versus signal to noise ratios in (ETU) channel for neighbor cell effect on Frequency domain based method.

5.2.3. Effect of Bandwidth on Frequency Domain Based Method

We can see in figure 5.7 and 5.8 the effect of the BW on frequency and time domain based methods. We can see that the performance is almost the same as the ratio $M/_N$ is the same.

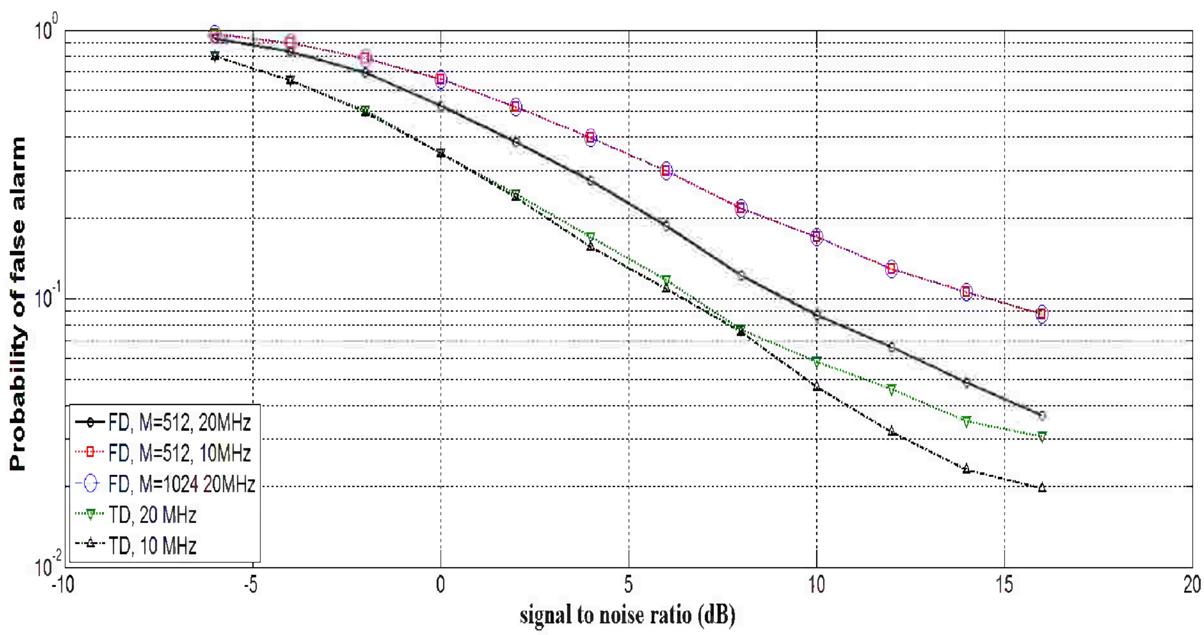

Figure 5.7 Probability of false alarms versus signal to noise ratios in (EPA) channel for the Frequency and time domain based method with different window step sizes M (10MHz Vs. 20 MHz)

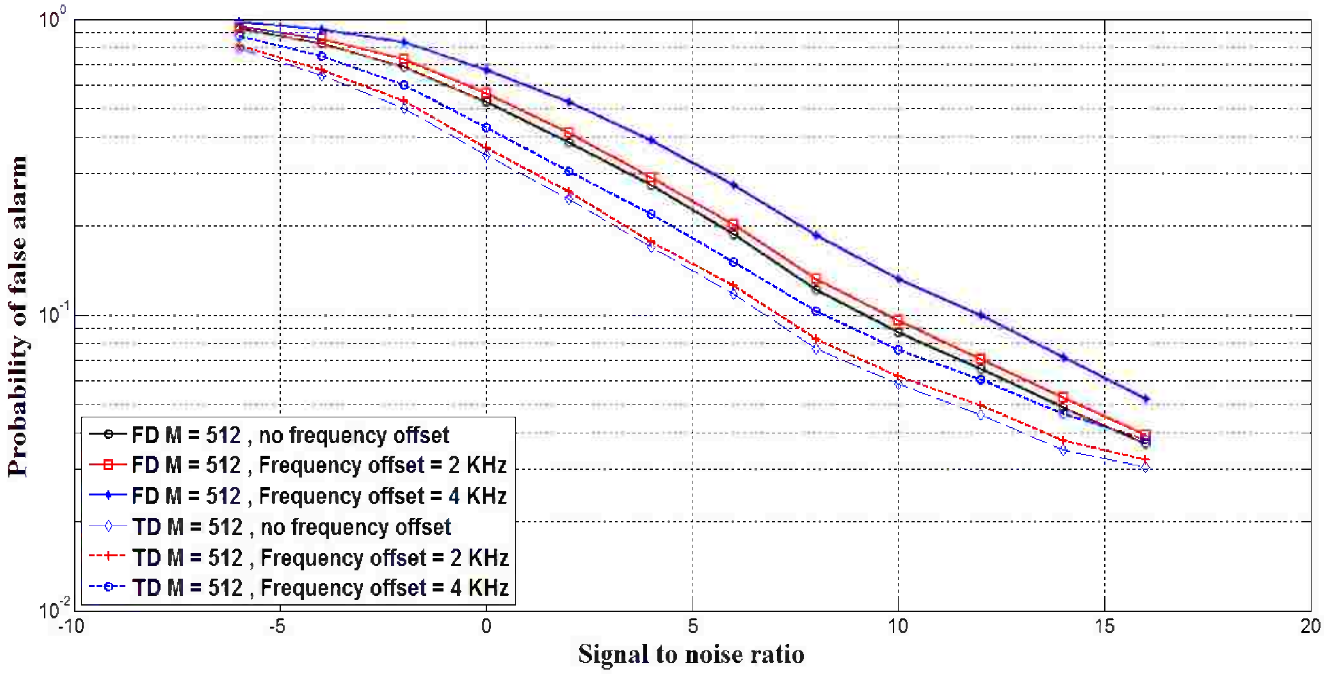

Figure 5.9 Probability of false alarms versus signal to noise ratios in (EPA) channel for the Frequency domain based method for M= 512 and time domain based method with different frequency offsets.

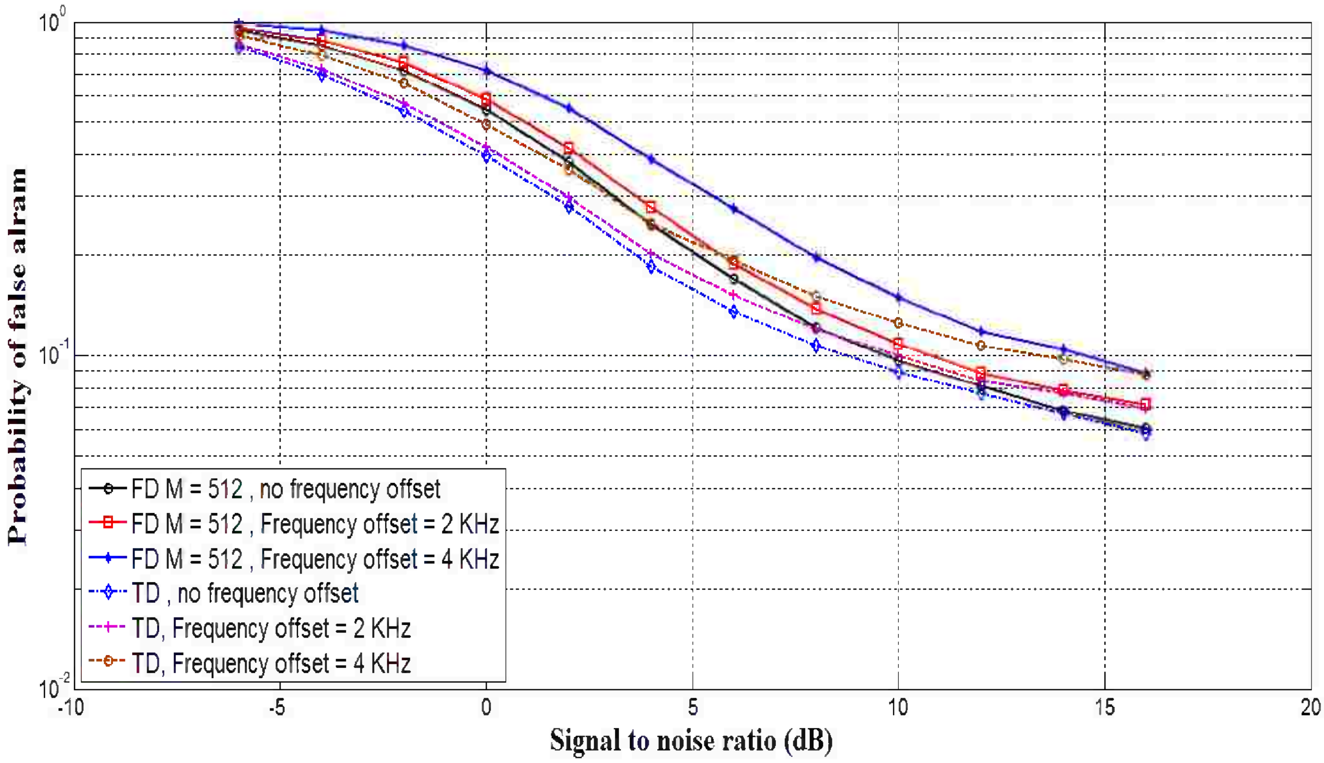

Figure 5.10 Probability of false alarms versus signal to noise ratios in (EVA) channel for the Frequency domain based method for M= 512 with different frequency offsets.

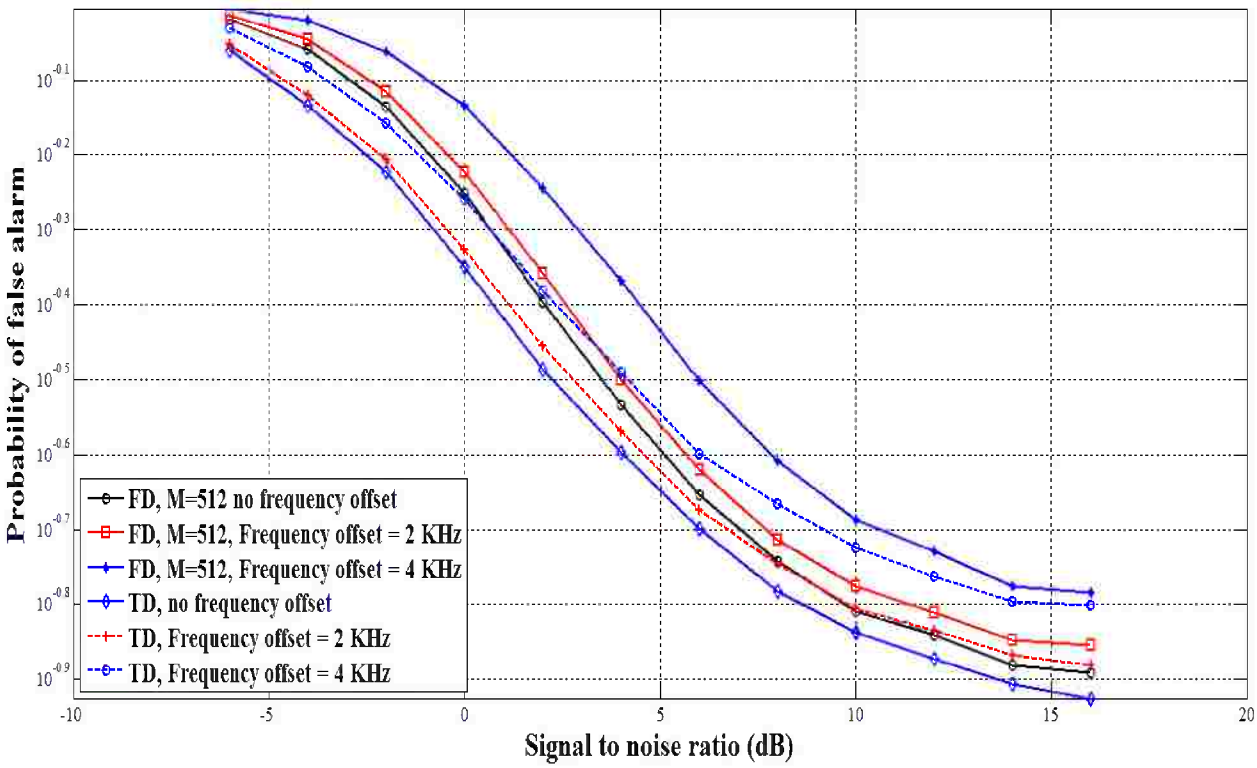

Figure 5.11 Probability of false alarms versus signal to noise ratios in (ETU) channel for the Frequency domain based method for M= 512 with different frequency offsets.

5.3. System Complexity

The main advantage of the frequency domain based method is the complexity reduction demonstrated by the reduced number of the computations in the frequency domain method compared to the time domain correlations.

In frequency domain based method, as mentioned in section III we run FFT with length N on the received frame and repeat this step with window step M.
Then, we combine every two consecutive FFT outputs with each other if needed (M= 2048).
After that, we perform a cross correlation with replicas of the three primary synchronization signals.
Finally we perform one IFFT with length (N) (or perform two IFFT operations, each one with length N, if needed in case of M=2048) and cross correlation with one primary synchronization signal in time domain.

But in time domain based method we perform cross correlation with replicas of the three primary synchronization signals in time domain and repeat this step every N symbols with window step equals one.

In tables 5.2 and 5.3 a comparison in the complexity (number of additions and complex multiplications) between the two methods with FFT size N = 2048 “we use FFT radix-2” and M = 512 for 20 MHz received frame is shown.

Figure 5.12 explains how the complexity of the frequency domain based method is calculated And figure 5.13 explains the complexity calculation of the conventional time domain method.

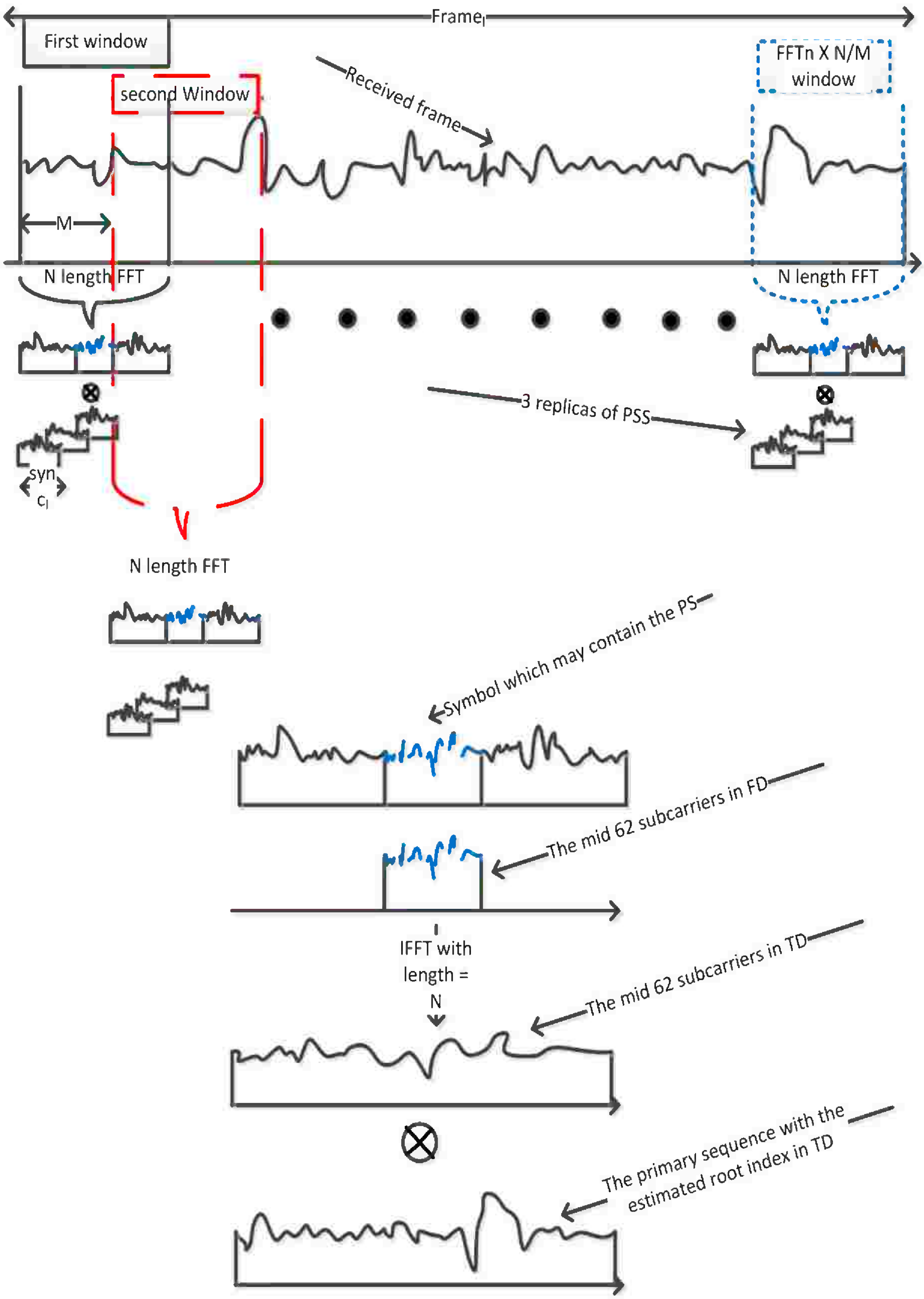

Figure 5.12 Complexity of the frequency domain based method

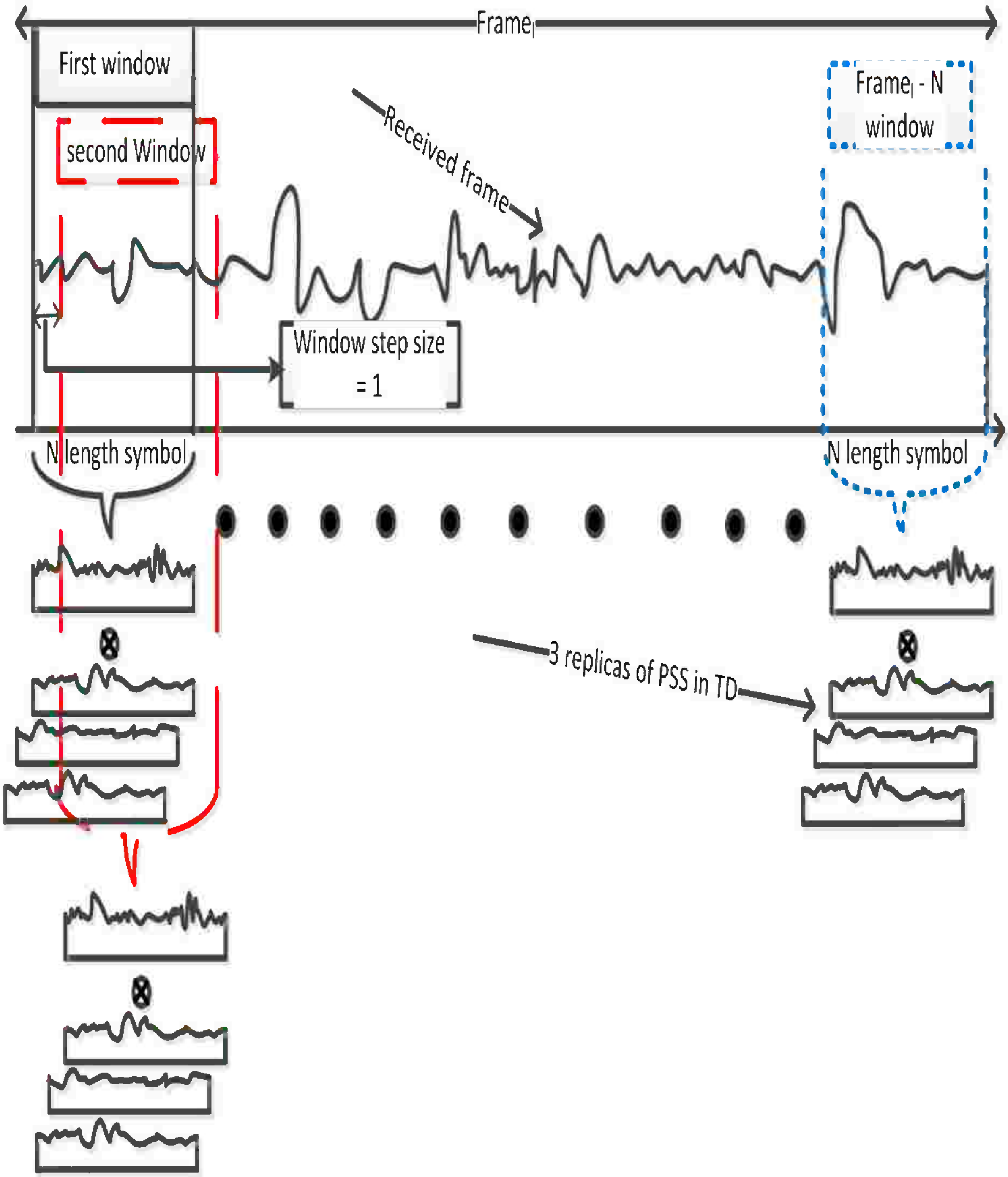

Figure 5.13 Complexity of the conventional time domain method

Domain	Operation	Number of additions		Number of Multiplications	
Frequency domain	FFT radix-2	$\mathrm{FFT_n} \times {}^{N}/_{M} \times N \log_2 N$	$1351,7 \times 10^4$	$\mathrm{FFT_n} \times {}^{N}/_{M} \times {}^{N}/_{2} \log_2 N$	$675,9 \times 10^4$
	Correlation	$\mathrm{FFT_n} \times {}^{N}/_{M} \times \mathrm{Sync_l} \times 3$	111.7×10^3	$\mathrm{FFT_n} \times {}^{N}/_{M} \times \mathrm{Sync_l} \times 3$	111.7×10^3
Time domain	IFFT radix-2	$2 \times N \log_2 N$	45056	$2 \times {}^{N}/_{2} \log_2 N$	22528
	Correlation	$N - 1$	2047	N	2048
Total	N/A	136.8×10^5		68.9×10^5	

Table 5.2 Complexity of frequency domain based method

Domain	Operation	Number of additions		Number of Multiplications	
Time domain	Correlation	$(\mathrm{Frame_l} - \mathrm{N}) \times 3 \times (\mathrm{N} - 1)$	1873.9×10^6	$(\mathrm{Frame_l} - \mathrm{N}) \times 3 \times (\mathrm{N})$	1874.8×10^6
Total	N/A	187.39×10^7		187.48×10^7	

Table 5.3 Complexity of time domain based method

Where $\mathrm{FFT_n}$ is number of symbols per frame with symbol length = N, $\mathrm{Sync_l}$ is the primary sequence length in frequency domain (62 samples) and $\mathrm{Frame_l}$ is the frame length. According to [24] the total number of complex multiplications in FFT radix-2 are ${}^{\mathrm{N}}/_{2} \log_2 \mathrm{N}$ and total number of additions are $\mathrm{N} \log_2 \mathrm{N}$.

We can see that the complexity of the frequency domain based method is less than the time domain based method with more than one hundred times in both additions and multiplications.