that OFDM/TDM can be used to reduce the required IBO, while achieving better BER than the conventional OFDM. For example, if the required BER=10^{-3}, the conventional OFDM (K = 1) cannot achieve this performance irrespective of P_s. Hence, to achieve BER=10^{-3} with reduced IBO we can use OFDM/TDM. When K increases from 16 to 32, the HPA power saturation level P_s can be reduced from 7 to 1 dB for BER=10^{-3}, respectively. Note that K = 64 can achieve BER=10^{-3} irrespective of P_s. This is because as K increases, the PAPR of the OFDM/TDM signal reduces and the signal is less degraded in the HPA. It can be seen from Fig. 5 that as K increases the required peak-power (i.e., IBO) of OFDM/TDM is reducing; for the average BER=10^{-3}, IBO can be reduced by about 1.3, 2.9 and 5.1 dB, compared to the conventional OFDM, when K=4, 16 and 64, respectively as shown in Fig. 5. The worst performance is achieved with the conventional

\[ f_{FM} T_s = 0.0014, \text{ QPSK, } L=16, \beta=0 \text{ dB} \]

**B. Power Efficiency Issue**

In this section, we discuss about the peak-power that is proportional to the PAPR of the transmitted signal. By definition, it can be shown that the theoretical PAPR of OFDM/TDM is proportional to number of subcarriers N_m (\approx N_c/K). The PAPR values (in decibels) of OFDM/TDM and conventional OFDM that represent the required IBO for QPSK constellation are given in Table I. It can be seen from the table that the PAPR of OFDM is as large as 24 dB, while for OFDM/TDM with K = 4 and 16 the PAPR reduces to 18 and 12 dB, respectively. Although the PAPR increases linearly with the number of subcarriers N_m, the probability that such a peak will occur decreases exponentially with N_m.

Figure 6 illustrates the theoretical and computer simulated complementary cdf (ccdf) of PAPR for OFDM/TDM as a function of K when N_c = 256. The theoretical ccdf of OFDM/TDM and the conventional OFDM is computed using (8). Also presented below are the computer simulation results for the OFDM/TDM signal transmission to confirm the validity of the theoretical analysis. Computer simulation results for ccdf of PAPR are obtained over 20 million OFDM/TDM frames. A fairly good agreement with theoretical and computer simulated results is seen that confirms the validity of our PAPR analysis based on the Gaussian approximation of the OFDM/TDM signal. It can be seen from the figure that, as K increases, the PAPR_{10\%} level, which the PAPR of OFDM/TDM exceeds with a probability of 10\%, is about 9, 8, 6.5 and 3 dB for K = 1 (OFDM), 4, 16 and 256 (SC), respectively.

We also consider the required peak transmit power because it is an important design parameter of transmit power amplifiers. For conventional OFDM transmission, high PAPR causes signal degradation due to non-linear power amplification and the BER performance degrades. Figure 7 illustrates the BER

![Fig. 4. BER vs. E_{b}/N_{0}](image)

![Fig. 5. BER vs. P_s.](image)

OFDM (K=1) due to large PAPR.