Chapter 7

CONCLUSION

In this work we have studied the behaviour of the flavour-changing quark-Z vertex arising from the penguin diagram, which involves the change of the external quark flavour, say from s to d, through the internal conversion into a quark of flavour j (j can be of flavour u, c or t in this case) with which a W boson is exchanged and accompanied by the emission of a virtual Z boson. The calculation of the flavour-changing quark-Z vertex function is performed in the 't Hooft-Feynman gauge.

The divergent term in the vertex function is isolated by using dimensional regularization. Renormalization is effected by a simple renormalization prescription, in which the counterterm is obtained from the improper on-shell vertex function (one-particle reducible diagram).

The $\bar{d}sZ$ vertex function is obtained without making any approximations and is expressed in terms of double integrals. The vertex function is found to contain 6 form factors A_j, B_j and C_j $(j = u,c,t)$. Our expression is thus more general than earlier work which involves only the C_j form factor. The double integrals has to be evaluated numerically in general. We have made the simplifying assumption that the masses of the external quarks and the momentum of the emitted Z boson are small compared to the mass of the W boson, so that the double integrals may be evaluated analytically.

We find that C_j grows quadratically with m_j, the mass of the internal quark j, and therefore is the dominant form factor for large m_j. The other form factors are much smaller; A_j grows only logarithmically with m_j, while B_j approaches a constant value as

m_j increases. For small value of m_j, however, we find that A_j is more dominant than the other two.

We have applied our result for the vertex in three different processes; $s \to dd\bar{d}$, $b \to ss\bar{s}$ and $b \to ds\bar{s}$. In the applications, we have dropped the term containing B_j because it is very small compared to the terms containing A_j or C_j. After analysis, the contribution of A_j term in $s \to dd\bar{d}$ is extremely small whereas its contribution in $b \to ss\bar{s}$ and $b \to ds\bar{s}$ are up to 0.31% and 0.29% respectively. The branching ratio for $s \to dd\bar{d}$ is obtained, i.e. 2.105×10^{-10}. The branching ratios for $b \to ss\bar{s}$ and $b \to ds\bar{s}$ are found to depend linearly on $\mathrm{Re}(\lambda_u \lambda_c^*)$ as shown in Figs. 6.3 and 6.4 respectively. The results show that the branching ratios of these 3 processes are very small, which are expected for processes in one-loop level.

Our work may be extended by applying the vertex function without making any approximation. Another extention is to study the contribution of the Z-penguin vertex function to CP violation. When k^2 is larger than a certain threshold value, absorptive part may appear in the vertex function. This absorptive part gives rise to nonzero decay rate asymmetry parameter, which may then serve as a measurement of its contribution to direct CP violation. Furthermore, the Z-penguin vertex may be applied to study the flavour-changing decays of the Z-boson. In such a case, k^2 shall not be omitted because $k^2 = M_z^2$, which is larger than M_w^2.