ABSTRACT

Integrated circuits have shown a dramatic increase in the frequency of operation in recent years, up to tens of GHz. AT GHz level frequencies, integrated spiral inductors and interdigitated capacitors suffer severe parasitic effects, making the accurate modeling of these devices more difficult. To aid in their design, the most common tool available for accurate modeling is numerical EM solvers. However, their use is often very time consuming and computationally very expensive.

This thesis proposes a lumped pi-model representation of the spiral inductor and interdigitated capacitor that is accurate up to and including the first resonant frequency of the device. Based upon the Partial Element Equivalent Circuit (PEEC) distributed model, approximations are made to simplify the distributed model down to a more useful pi-lumped circuit model that enables the designer to visualize the parasitic impedances that each device experiences. Other lumped circuit models are outlined in the literature, but the component values are determined using empirically derived or approximated formulas. The method in this thesis is more rigorous and physically derived, using the partial capacitance matrix and partial inductance matrix, along with a resistance matrix that takes into account the skin effect and, in the case of the spiral inductor, the eddy current effect.

The thesis begins with a review of the PEEC technique. An improved resistance matrix is derived that works for a wide range of inductor geometries by more accurately accounting for the eddy current effect and skin effect. A resistance matrix that is dependent only upon the skin effect is derived for interdigitated capacitors. The approximations made to simplify the PEEC model to a lumped pi-model are reviewed for both the spiral inductor and interdigitated capacitor. In addition, a general technique for the de-embedding of RF passive devices is reviewed. There are many de-embedding techniques outlined in the literature for smaller active devices, but these techniques are often erroneously applied to larger passive devices. The parasitics that typically need to be de-embedded in an RF passive device test structure are discussed, and a few techniques for accurately dealing with these parasitics are introduced. The thesis concludes with a comparison of the 2-port S-parameters, inductor Q, and effective inductance arrived with our model to that arrived with ADS RF Momentum for a set of five spiral inductors. We also compare our model to de-embedded measured data for a 1 nH spiral inductor. In the case of the interdigitated capacitor, we compare the 2-port S-parameters, 2-port differential resistance, and effective capacitance calculated with our model to that calculated with ADS RF Momentum.