DESIGN OF MMICs EMPLOYING WHISPERING-GALLERY MODE DIELECTRIC RESONATORS AT MICROWAVE and MILLIMETER WAVE FREQUENCIES

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ABSTRACT

A simple theoretical model for predicting the resonant frequencies of the modes of the whispering - gallery (WG) mode dielectric resonators MICs (Microwave Integrated Circuits) at microwave and millimetre wave frequencies is presented. The unsymmetric field distribution for WGE mode in the axial direction is taken into account. The theoretical results are found to be in good agreement with the practical results taken at microwaves C-X bands. In addition, the variation of resonant modes against dielectric resonator's dimensions and dielectric constant is modelled. The effect of the width of dielectric substrate on resonant modes is also illustrated.

1. INTRODUCTION

For oscillator stabilisation purposes traditional cavity resonators and dielectric resonators are usually employed. Cavity resonators are difficult to integrate with planar millimeter wave circuits, therefore in many applications they are replaced by TE and TM mode dielectric resonators. However conventional dielectric resonators become very small at
millimeter wave frequencies and are therefore difficult to handle and to manufacture with sufficient dimensional accuracy. If the geometrical structure of conventional mode DR is changed slightly, it is possible to generate modes known as whispering gallery modes [1]-[9]. DRs carrying such modes have quite large diameters even at millimeter wave frequencies. Apart from having large dimensions the main advantage as compared to the commercial resonators (e.g. TE_{013}) is high Q factor which is very useful for the application in oscillators at millimeter wave frequencies. Earlier a theoretical coupling model is reported [8] in order to compute quality factors directly against the spacing between a WG mode dielectric resonator and the edge of a microstrip line based on a dielectric waveguide model. The oscillator employing dielectric resonator operating in WG mode featuring low phase noise and adequate power is reported by author elsewhere [9].

Dielectric resonators (DRs) operating in whispering gallery modes have certain advantages over the conventional mode DRs. They have high Q-factors and larger dimensions at mm-wave frequencies. For practical use DRs are normally placed on top of the substrates in order to couple with the external microstrip line. For this case, a simple model based on dielectric waveguide in order to predict the operating resonant frequencies of WG mode planar structured DRs is proposed in this paper.

Among earlier models Jiao et al [2] produced the simplest and most accurate model. He considered the evanescent field inside the model caustic 'a'; and outside the boundary 'a' (Fig. 1). This enabled him to obtain a 4 x 4 matrix eigen equation by matching the tangential components of the electric and magnetic fields across the dielectric boundary and the modal caustic. In order to consider the field variation in the axial direction he matched the electric radial component and its derivative with respect to r at \( z = \pm d \). This gave him the second eigen