Design and Characterisation of a Novel Diamond Resonator

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Abstract: In this paper, the resonant frequency and quality factor of a novel coplanar waveguide (cpw) diamond shaped resonator was analysed using Advanced Design System (ADS-2009) finite element software. The diamond resonator was compared with the cpw radial stub resonator on gallium arsenide (GaAs); the work indicated that the diamond resonator had a smaller physical size and higher quality factor (Q) at milli-metric wave frequencies. Experimentally measured diamond cpw resonators fabricated on gallium arsenide (GaAs) were in good agreement with the simulated results.

Index Terms- Diamond resonator, resonant frequency, radial stub resonator and quality factor

I. INTRODUCTION

Microwave resonators have many applications in microwave and milli-metric wave circuits. For example, it is an important component in the design of microwave filters [1-2], microwave oscillators [3] and microstrip antennas [4-5] . The requirements for these integrated resonators include small physical size to increase packing density in microwave monolithic integrated circuits (MMIC), high frequency of resonance and low loss i.e. a high Q quality factor.

In this paper, the novel diamond resonator was designed using the software package Advanced Design Systems (ADS-2009), fabricated on a gallium arsenide substrate and RF characterised to 110GHz using a network analyser.. The structure was designed as the resonant element to realize a planar integrated oscillator operating in milli-metric to terahertz frequencies. The novel cpw diamond shaped resonator was found to have a higher Q when compared with cpw quarter wavelength [6] and radial stub resonator [7] when operating at the same resonant frequency.

II. DESIGN OF DIAMOND RESONATORS AND FABRICATION

Figure 1 shows a schematic view of the coplanar waveguide diamond resonator. The resonator has a metallised thickness of T and an inner length L with a sectorial angle θ, the apex corner of the resonator is directly fed from a cpw 50 Ohm line. The structure can be fabricated on a dielectric substrate with a relative permittivity ε_r and a thickness H. The structure was analysed by setting it up as a finite element model using the electromagnetic package in ADS. Particular care was exercised in choosing the mesh size to obtain realistic results particularly small L, a requirement for the high frequency resonators. In practise the mesh size was restricted by the available desk top computer. The resonators analysed were on gallium arsenide semi-insulating substrate of relative permittivity 12.9 and thickness of 620µm. The cpw 50Ω line had a width W of 60µm and a gap G of 40µm, these were calculate using the ADS 'line calculator'. The structure contained no air bridging to equalise potential of the two earth planes. It was found by reducing the inner length L of the resonator the resonant frequency was increased.

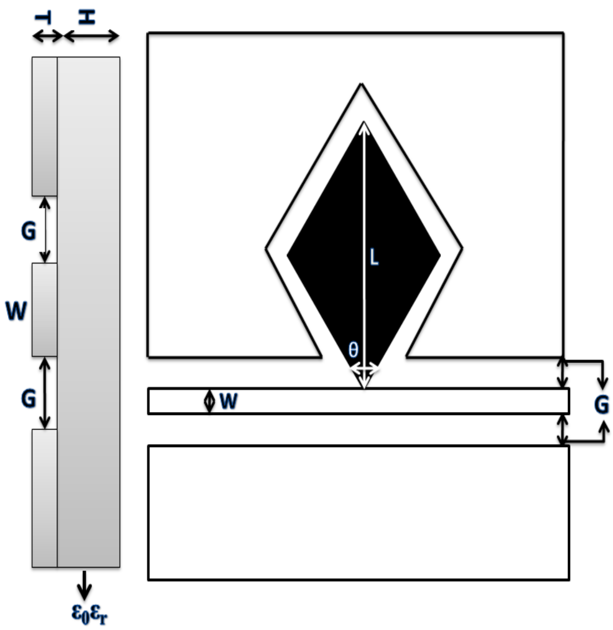

Fig.1 CPW Diamond resonator

III. SIMULATION RESULTS

The resonant frequency of a CPW radial line resonator is difficult to calculate because of the closed form equation reported in [8], this was overcome by using a polynomial equation to fit the simulated and measured results [9]. A similar method for characterising the diamond resonator was adopted, and the simulated resonant frequency (f_0) as a function of L at a constant sectorial angle of 60 degrees is given as a polynomial equation (1).

$$f_0 = 3221L^4 - 8368L^3 + 7827L^2 - 3180L + 530.9 \quad (1)$$

The coefficients of the polynomial equation will be modified for different sectorial angles. Figure.2 shows a comparison between the simulated cpw diamond and radial stub resonators. The results clearly show that the diamond geometry will resonate at a higher frequency than the standard radial stub resonator of a comparable length. The plot shows that for a radial stub resonator with a radius of 0.6mm the resonant frequency was 32.56 GHz, whereas for the diamond resonator with an inner length of 0.6mm the resonant frequency was 44.87 GHz. The diamond resonator also has an overall smaller physical outline when compared to radial and quarter wavelength stub resonators which is shown in the Figure.3. From the plot the diamond resonator of inner length 0.6 mm required approximately 55 % of the chip area when compare to the radial stub resonator of radius 0.6mm.

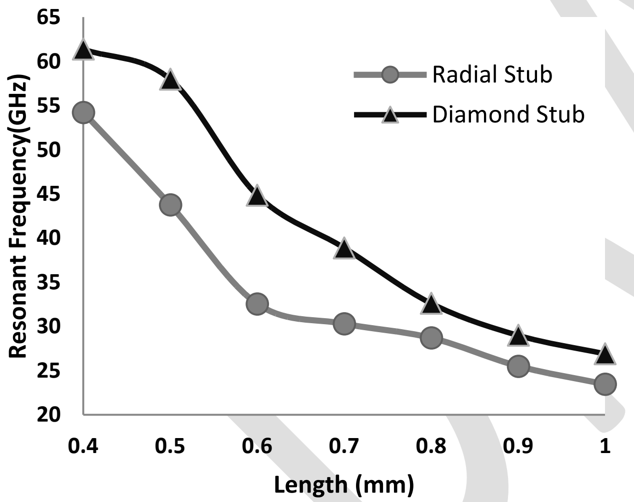

Fig.2 Comparison of the resonant frequency of cpw Diamond and Radial stub resonators as a function of resonator length.

IV. EXPERIMENTAL RESULTS

A number of cpw diamond resonators with a sectorial angle of 60° with an inner length of 0.1 to 1.0 mm were fabricated on a 620 µm thick GaAs wafer. The metallization thickness of the resonator structure was 0.4 µm and the structure was fed using 50 Ohm cpw line which is shown in Figure.1. These were fabricated in James Watt Nanofabrication Centre at University of Glasgow

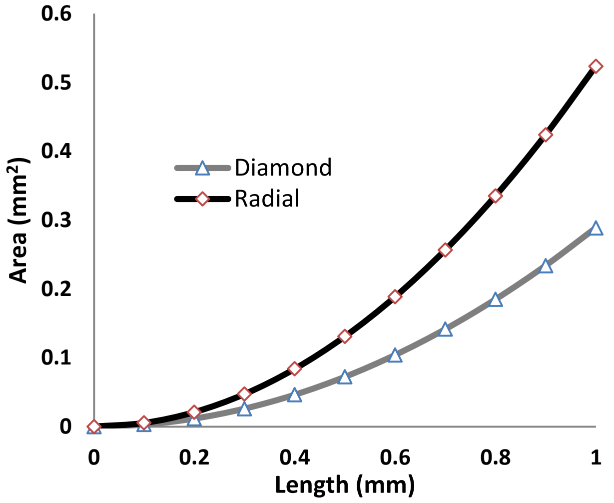

Fig.3 Area of Diamond and Radial stub resonators.

The resonators were characterised using two port s-parameter measurements from 100 MHz to 110 GHz using calibrated RF probes (Cascade MicroTech ACP11-100) coupled to an Agilent E8364b network analyzer at the Nanotechnology Centre, University of Glasgow. The experimental resonant frequency was defined when s_{21} approached a low loss and the s_{11} a high return loss.

The experimental measured and simulated resonant frequency of diamond resonators with increasing L are directly compared in Figure 4. The plot shows very good agreement between experiment and simulation for inner resonator length varying from 1 to approximately 0.3 mm. The experimental result for L < 0.3mm departs from the simulation and is thought to be due to restriction in mesh size and experimental parasitic effects not taken into account in the simulation. The Q of the resonator structures was compared using

$$Q = \frac{Energy\ stored}{Energy\ dissipated} = \frac{f_0}{\Delta f} \quad (2)$$

where Δf is the 3dB bandwidth. The 0.6 mm and 60° sectorial angle diamond resonators had a simulated Q-factor of 46; the measured Q-factor was 38, whereas for the radial stub the simulated Q-factor was 16. Higher Q factors will be possible with increased metallisation thickness.

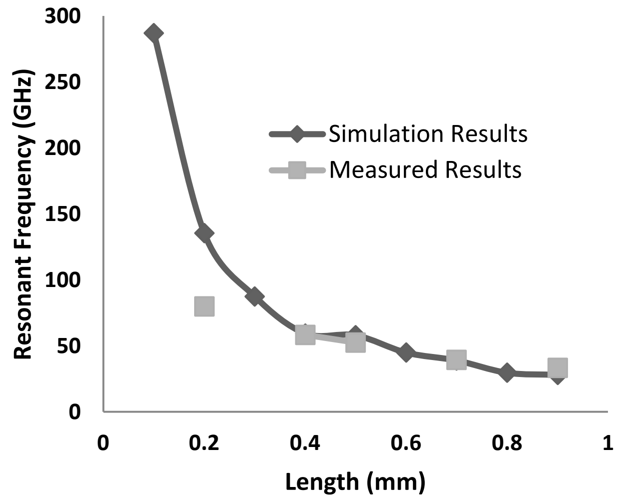

Fig.4 Measured resonance frequency of a diamond resonator against length by keeping the sectorial angle as constant.

V. CONCLUSION AND DISCUSSION

A novel planar diamond resonator on GaAs has been simulated for different inner lengths L. The resonant frequency was described as a function of the inner length L using a polynomial equation similar in form used to describe the radial resonator [8]. The work found that the diamond resonator had a smaller physical outline when compared to a comparable radial resonator making it attractive for increasing the packing density in MMIC technologies. Diamond resonators were fabricated and experimentally measured with very good agreement with simulation results.

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VI. REFERENCE

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