Novel Multi-strip Resonator and Filter

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Abstract — **Multi-strip resonators are proposed to reduce the resonator size , and improve spurious and loss property. The number and the distance of strips are controlled to balance these properties. Computer simulation and experimental result agreed quite well to verify the simulated results. A two stage BPF is designed and fabricated, indicating the feasibility of the new resonator.**

I. INTRODUCTION

Artificial dielectrics are utilized for miniaturization of microwave resonators since their relative permittivity easily exceeds 100 [1]. If one reduces the number of metal strips as shown in Fig.1, the artificial dielectric resonator gradually approaches to a single-strip resonator. If we start from a single strip resonator in Fig.1, on the contrary, its resonant frequency decreases according as metal strips are added to couple with the original strip resonator. Lowering of the resonant frequency is equivalent to shrinking of the size on the basis of the same resonant frequency.

Multi-strip resonators are in the midway between artificial dielectric resonator and a single strip resonator. Since more effective way to obtain a higher permittivity is to increase the density of metal strips in artificial dielectrics, we will examine the effect of the strip distances along with that of the number of strips that makes a multiple-strip resonator.

Another important parameter of a resonator is the unloaded Q that accounts for the energy loss. It is especially important for a narrow bandwidth and multistage bandpass filter. In addition, a good spurious property is also critical for the modern filter application under the intricate use of frequency bands. These two properties will also be addressed with computer simulation and experiment. Some examples of bandpass filter will show the efficacy of the proposed resonators.

Though two-metal-strip resonator has already been studied by ourselves [2] and others [3] in order to miniaturize strip resonators, multi-strip resonator nor improvement of Q value have ever been proposed.

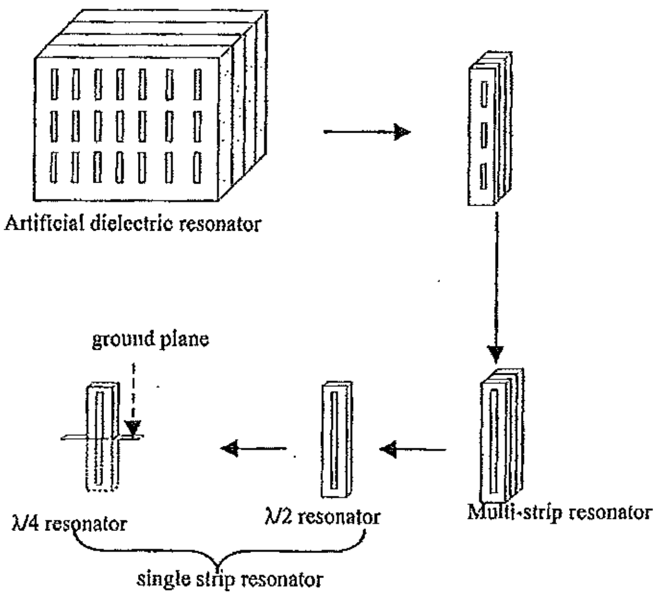

Fig.1 Transition of artificial dielectric resonator to a single strip resonator

II. DEPENDENCE ON NUMBER OF STRIPS

Figure 2 shows the simulated structure with varied number of strips (N) by a commercial software Sonnet. The interdigital configuration of strips comes from the analogy with the face-centered lattice structure in an artificial dielectric that gives the maximum permittivity. For the constant strip spacing 0.7 mm , the resonant frequency of the fundamental mode , spurious index (SI) and conductor Q are calculated in Fig.3. The spurious index is defined as

$$\text{spurious index (SI)} = \frac{\text{2nd higher mode frequency}}{\text{fundamental mode frequncy}}$$

Since the radiation loss is suppressed and the dielectric loss is simply expressed by tan δ of the embedding dielectric in our closed structure , we only consider conductor loss.

The important result is the increase of Q_c, which suggests the possibility of loss reduction accompanied with miniaturization. Redistribution of the current in the resonator decreases its intensity to reduce the conductor loss.

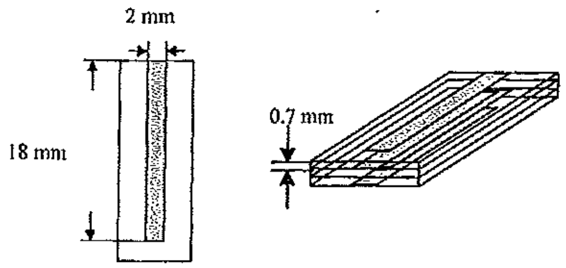

Fig.2 Structure of multi-strip interdigital resonator

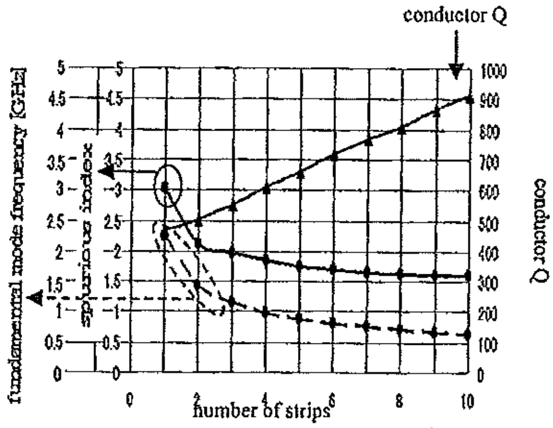

Fig.3 Simulation results for fundamental mode frequency , spurious index and conductor Q versus number of strips (Strip spacing is 0.7mm)

III. DEPENDENCE ON STRIPS SPACINGS

In an artificial dielectric resonator, the increase of molecule density augments the effective permittivity [1], resulting in the lower resonant frequency. The same thing is true for a multi-strip resonator, which could be attributed to the increase of loading capacitance. Figure 4 shows the simulated results for fundamental mode frequency (f_0), spurious index (SI) and conductor Q (Q_c) as functions of the strip spacing for a 2-strip resonator.

The frequency f_0 lowers as is expected for narrower spacing, while SI increases significantly to the expectation of good spurious property. The deterioration of Q_c is resulted from the concentration of rf current.

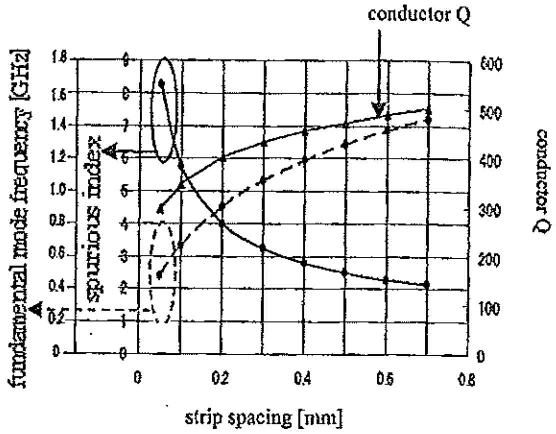

Fig.4 Simulated results for fundamental mode frequency , spurious index and conductor Q versus strip spacing (Number of strips is 2)

IV. EXPERIMENT ON RESONATORS

BT resin substrate is prepared for fabrication of a multi-layered structure. Its thickness is 0.7mm and permittivity = 3.27, tan δ = 0.0036. Though Cu thin film of 18μm is attached on the both sides, the effective conductivity is expected to be only 70 or 80 % of the bulk copper due to the surface-roughing for adhesion to the substrate.

The experimental data for f_0 and Q_c are plotted in Fig.5 together with the simulation results versus the number of metal strips. Though the fundamental mode frequency agrees very well, conductor Q is lower than the simulation, which is due to the lower conductivity mentioned above. But the important thing is that we can improve Q_c appreciably by increasing the number of strips. Thus, we can choose either of two typical ways of improvement according to the circuit requirement.

- Increase of number of metal strips (Figs.3 and 5)
  - o Decrease of resonator length with increase of its thickness, but decrease of its volume
  - ◎Increase of unloaded Q
  - × Decrease of spurious index from 3 to around 2

- Decrease of metal spacing (Fig.4)
  - ◎Decrease of resonator length and thickness , drastic decrease of volume
  - × Slight decrease of unloaded Q
  - ◎ Increase of spurious index

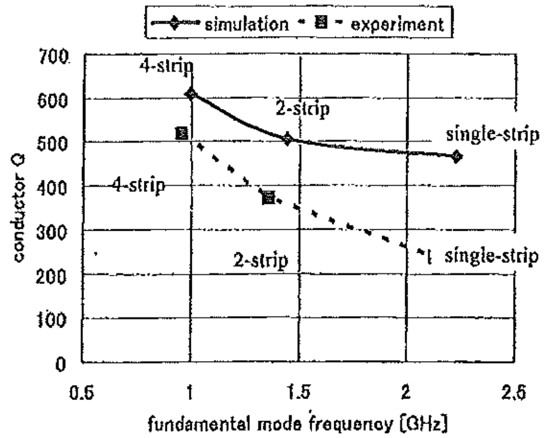

Fig5. Simulated and measured relations for fundamental mode frequency and conductor Q taking number of strips as a parameter (strip spacing is 0.7 mm)

V. FABRICATION OF BPF

We have designed and fabricated a 2-stage Butterworth BPF with 4-strip resonators, the structure of which is depicted in Fig.6. The designed center frequency is 0.955 GHz and bandwidth is 0.02 GHz. The substrates are 0.7 mm thickness BT resin coated with Cu thin film of 18μm thickness as before. The simulated and measured $|S_{21}|$ and $|S_{11}|$ are shown in Figs.7 and 8 as the narrow and global responses, respectively. They show quite good agreement except that the measured insertion loss is 1.3 times as high as the simulated value. The spurious index in Section 3 indicates rather poor value 2.1 for the 4-strip resonator, but Fig.8 shows that the first spurious at 1.75 GHz is not exited strongly due to the mismatch of the excitation field and the spurious mode field. As a result, the spurious characteristics of this filter turned out very good.

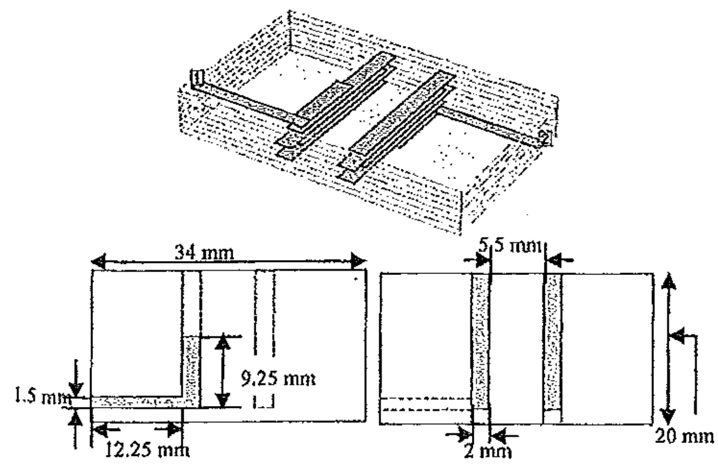

Fig.6 Fabricated 2-stage BPF with 4-strip resonators (BT resin substrate of 0.7 mm thickness, 18μm Cu thickness)

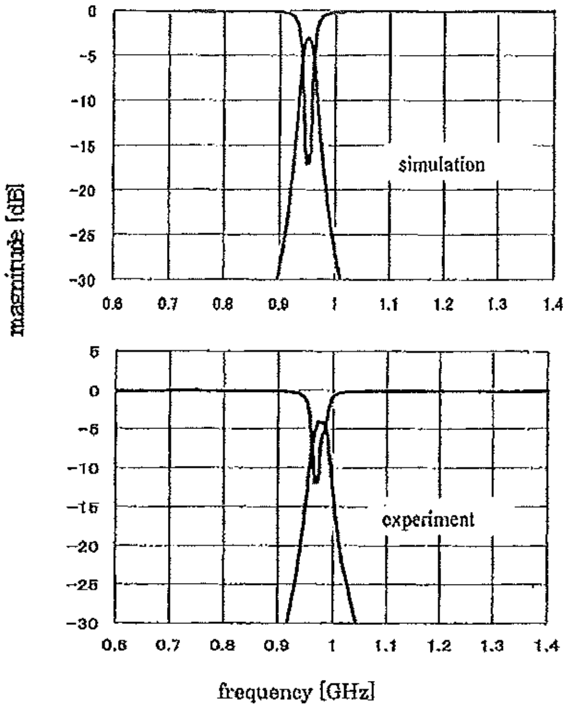

Fig.7 Simulation and measured narrow-band response of 2-stage BPF with 4-strip resonators

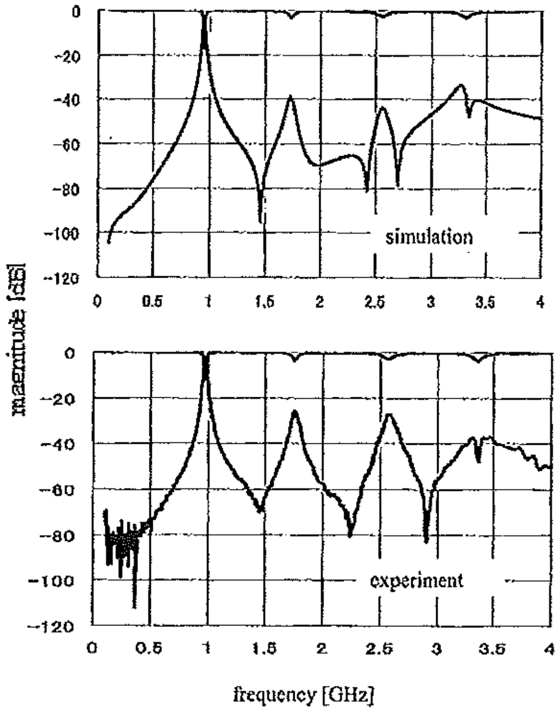

Fig.8 Simulated and measured global response of 2-stage BPF with 4-strip resonators

VI. CONCLUSION

A multi-strip resonator with interdigital configuration has been proposed from the analogy with artificial dielectric resonators. Miniaturization, improvement of spurious property and/or loss reduction could be attained with proper selection of number and distance of strips. The feasibility was verified by simulation and supporting experiment.

A two stage BPF was fabricated using 4-strip resonators to show a perfect agreement with the design and simulation.

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