Edge-Coupled Microstrip Loop Resonators with Capacitive Loading

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***Abstract*—Novel edge-coupled microstrip loop resonators with capacitive loading have been developed. A preliminary investigation has shown that the novel coupled resonators have a smaller size and similar frequency responses as compared with the conventional coupled microstrip line resonators. This makes them attractive to the monolithic microwave integrated circuits (MMIC) and the microwave superconductive circuits where size reduction is of primary importance.**

I. Introduction

The EDGE-COUPLED microstrip line resonators find wide applications in microwave circuits [1]. However, the circuits constructed with them occupy a fairly large surface area, which has become an obstacle for miniaturization of microwave integrated circuits (MIC) where the utilization of MIC surface area in a highly efficient manner is required [2]. To tackle this problem, we propose in this paper a novel kind of coupled resonator, that is the edge-coupled microstrip loop resonators with capacitive loading. Some results of the preliminary investigation are presented and have shown that the novel coupled resonators have a smaller size and similar frequency responses as compared with the conventional coupled microstrip line resonators.

II. Novel Coupled Resonators

The conventional coupled microstrip line resonators are shown in Fig. 1(a). In consideration of the fact that both the current and the charge distributions are most concentrated along the edges; and the coupling is mainly due to the adjacent edge-fields [3], it would seem that the electrical properties would not be changed much if the internal parts of microstrips are taken off. Furthermore, in order to be able to reduce the physical length of the coupled resonators while keeping the same electrical length, some capacitive fingers (open stubs) are loaded inside the loop along the edges as indicated in Fig. 1(b). Thus the so-called edge-coupled microstrip loop resonators with capacitive loading are formed. It can be expected that the even- and odd-mode phase velocity of the novel coupled resonators will be reduced as more fingers are included as described below.

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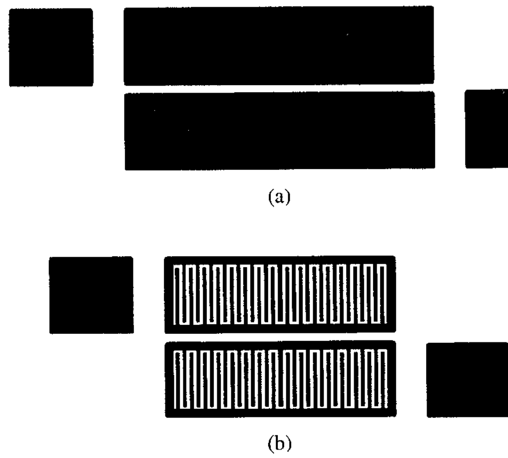

Fig. 1. (a) Conventional coupled microstrip line resonators; (b) edge-coupled microstrip loop resonators with capacitive loading.

Let W_f and l_f denote the finger width and length, respectively. We note that 1) l_f is smaller than the width of the associated microstrip line whose width is usually smaller than quarter-wavelength of operation frequency to avoid the propagation of higher-order modes; and 2) the two edge-strips of each finger loaded loop are connected at both ends to form an even-mode resonant cavity for each loaded loop. Therefore, for our purpose, we assume that $l_f \ll \lambda_g/4$, where λ_g is the guided wavelength of the finger, and no coupling between fingers. It is unlikely that these two assumptions may affect the foundation on which the physical mechanism underlying the phase velocity shift is based because both will only influence the value of the loaded capacitance. Thus the loaded capacitance for each finger may be written as

$$C_f = \epsilon_{eff} C_a l_f \tag{1}$$

where C_a is the capacitance (per unit length) of the finger with the dielectric replaced by air and ϵ_{eff} the effective dielectric constant, whose formulation can be found elsewhere [4]. If C_f is periodically loaded along a length L with equal finger width and space, the number of loaded fingers is $L/(2W_f)$ and thus the total loaded capacitance is given by

$$C_{total} = \frac{C_f}{2W_f/h} \cdot (L/h) = C \cdot (L/h) \tag{2}$$

with C the capacitance per unit length which is normalized by dielectric thick h. It is clear that for a given normalized length L/h, C_{total} is proportional to C. A plot for the normalized

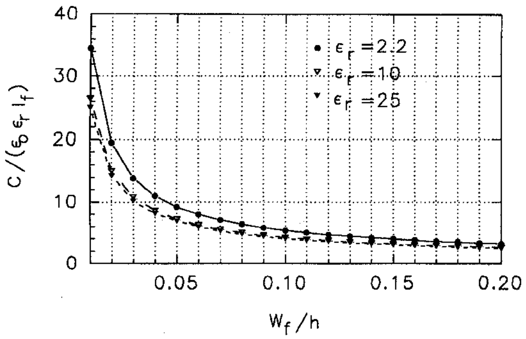

Fig. 2. Loading capacitance as a function of finger width.

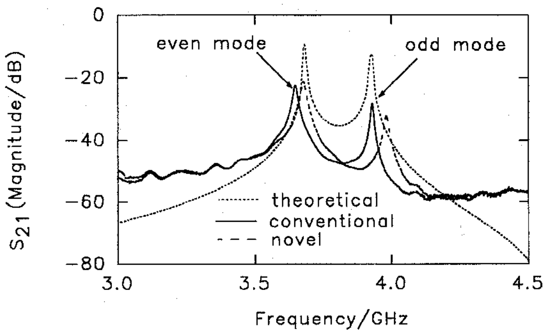

Fig. 3. Modeled and measured frequency responses of coupled resonators.

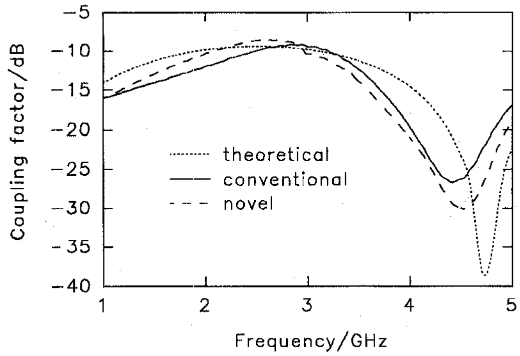

Fig. 4. Modeled and measured coupling factors.

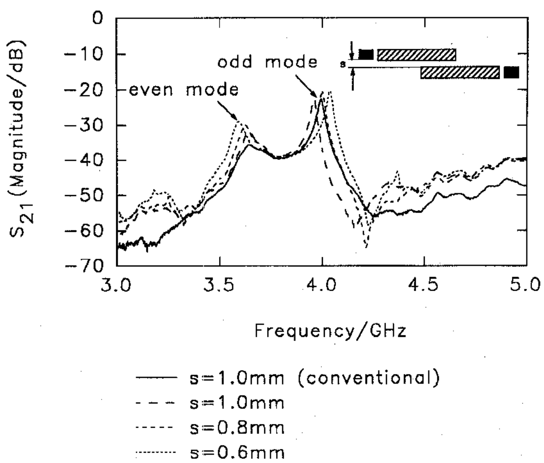

Fig. 5. Measured resonant frequency responses of half-overlapped coupled loop resonators.

C against W_f/h is shown in Fig. 2, where one can see that C is increased as the finger width decreases. According to the theory of periodic structures [4], the phase velocity of the finger loaded transmission line will be reduced as more fingers are included, which has been observed in our experiments [5]. It follows that the even- and odd-mode phase velocity of the novel coupled resonators is decreased as the number of the fingers increases. This would enable one to make compact circuits and to utilize surface area in a highly efficient manner.

III. Experiments

In our experiments, all resonators were realized on RT/Duroid with dielectric thick $h = 1.57$ mm and relative dielectric constant $\epsilon_r = 2.2$. All measurements were carried out on the HP 8720A network analyzer. Fig. 3 plots the resonant frequency responses of a pair of conventional coupled microstrip line resonators (each has a size of 6.6 mm × 27.04 mm) and a pair of novel coupled microstrip loop resonators (each has a outline loop of 6.6 mm × 20 mm with a strip width of 0.5 mm and is loaded with 31 equally spaced (0.3 mm) fingers having $l_f = 5.2$ mm and $W_f = 0.3$ mm except for the middle one with $W_f = 0.4$ mm). The dash line results from an ideal theoretical model (lossless and nondispersion) [6] while the full and broken lines are the measured results. Two distinct resonances are observable for the even-mode and odd-mode. Although there are some differences between the theoretical and measured results due to the nonideal situations of the device under test, the two pairs of coupled resonators bear the resemble measured frequency responses (this is also true for the phase responses). The coupling factors were modeled and measured by short-circuited the feeding gaps and are shown in Fig. 4, where we see again the similar measured frequency responses. However, it should be noted that the novel coupled resonators occupy only 0.74 area of the conventional ones (refer to Fig. 1). Although this reduction is not an optimal one, it at least demonstrates the capability for reducing size without changing frequency responses when the conventional coupled resonators are replaced by the novel ones.

For some applications such as bandpass filters, the coupled resonators are only overlapped by half. The measured resonator frequency responses of such half-overlapped coupled resonators are shown in Fig. 5. Again the similar resonator frequency responses of the conventional and the novel coupled resonators are observable. It can also be seen that the separation of the two resonances for even-mode and odd-mode of the novel coupled resonators is increased as the coupling space is reduced. This means that the separation of the even-mode and odd-mode phase velocities is increased as the coupling space decreases. This tendency is in agreement with that of the conventional coupled microstrip line resonators.

IV. Conclusion

The novel edge-coupled microstrip loop resonators have been developed. It has been shown that the novel coupled resonators has not only a smaller size which utilizes the circuit surface in a highly efficient manner, but also a compatible outline structure as well as similar frequency responses as compared with the conventional coupled microstrip line resonators. This implies that more compact circuits can be realized by replacing the conventional coupled microstrip line resonators with the novel ones, which can be benefit to the monolithic microwave integrated circuits (MMIC) and the microwave superconductive circuits.

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