AN ELLIPTIC-FUNCTION LOW-PASS FILTER WITH A RING-RESONATOR

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Abstract – **This paper proposed a new elliptic-function low-pass filter (LPF). This LPF includes a ring resonator in order to create a transmission zero just above its cut-off frequency, and can eliminate coupled-lines in conventional elliptic-function LPFs, resulting in a more simplified design and fabrication of the elliptic-function LPF. The LPF can realize a sharp frequency selectivity which is especially useful for reduction of spurious spectra in feeding networks for antennas.**

I. INTRODUCTION

A low-pass filter (LPF) is a basic building block in a feeding circuit of an antenna, and it filters out spurious spectra in an RF active module. Especially as LPFs, elliptic-function LPFs are often preferred, because they can create a transmission zero just above its cut-off frequency [1] and result in a sharper frequency selectivity than all-pole filters such as Chebyshev and Butterworth LPFs without the transmission zeros [2]. In planar circuits, conventional elliptic-function LPFs have been realized by using coupled-lines in order to obtain TZs [3][4]. However, high precisions in its line-widths and spacings are required in its fabrication process in order to meet required specifications of the LPF, and a rigorous full-wave electromagnetic analysis may be required in its design.

This paper proposes a novel elliptic-function LPF, which includes no coupled-line and consists simply of a ring resonator. Although the ring resonator has been conventionally used for band-pass filters and for measurements of permittivity of a dielectric material [5], it is used in this paper as a low-pass element for realizing the transmission zero. The LPF can be fabricated simply as a cascade of transmission lines and open-circuited stubs, tolerating more degrees of fabrication errors than the conventional LPFs.

II. NOVEL LOW-PASS FILTER WITH A RING-RESONATOR

Fig. 1 shows a conventional circuit section for the transmission zero (TZ) in a LPF. The TZ can be realized by a series-connected parallel-resonant circuit, and the capacitor in the resonant circuit is realized by a coupled-line. As mentioned above, the design and fabrication of the coupled-line must be precise enough for stringent requirements in the filter characteristics.

Fig. 2(a) shows the proposed circuit for creating the TZ, which is a symmetrically-folded elliptic-function

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LPF with its number of stage N = 4 [6]. It includes both positive- and negative-valued J-inverters in order for the TZ, and all the parameters in the LPF can be synthesized uniquely by giving its transmission characteristics by an elliptic function [1][6]. By adopting the equivalences shown in Figs. 3(a) and (b), the circuit in Fig. 2(a) can be transformed into the one in Fig. 2(b), resulting in no negative-valued J-inverter. Since the positive-valued J-inverters, shunt capacitors, and series inductors can be realized by quarter-wavelength transmission lines, open-circuited stubs, and high-impedance transmission lines, respectively, the circuit in Fig. 2(b) can be realized as a ring-resonator with the open-circuited stubs as shown in Fig. 2(c). In Fig. 2(c), characteristic impedances (Z_1, Z_2, Z_C, Z_L) and electrical lengths ($\theta_1, \theta_2, \theta_C, \theta_L$) of each transmission line are given approximately so as to satisfy

$$Z_C^{-1} \tan\theta_L = \omega_c C_1 \tag{1a}$$

$$Z_L \tan\theta_L = \omega_c L_2 = \omega_c C_2^{-1} \tag{1b}$$

$$(Z_1, Z_2) = (J_1^{-1}, J_2) \tag{1c}$$

$$\theta_1 = \theta_2 = \frac{\pi}{2}, \tag{1d}$$

In the above equations, the electrical lengths are defined at a cut-off frequency $\omega_c = 2\pi f_c$ of the LPF. The LPF includes no coupled-line, and it can be fabricated simply as a cascade of transmission lines and open-circuited stubs, without the need of precise control of line-widths and spacing as in the conventional coupled-line LPFs.

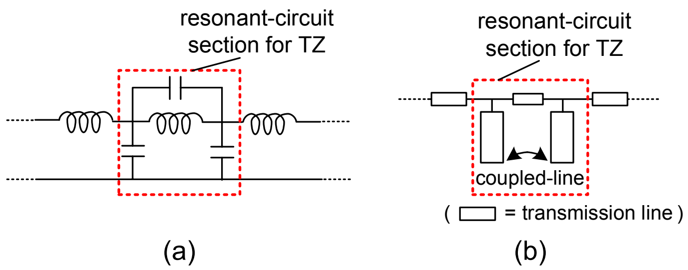

Fig. 1. (a) Conventional elliptic-function low-pass circuit section with series-connected parallel-resonant circuit, (b) Distributed-element circuit of (a) with a coupled-line.

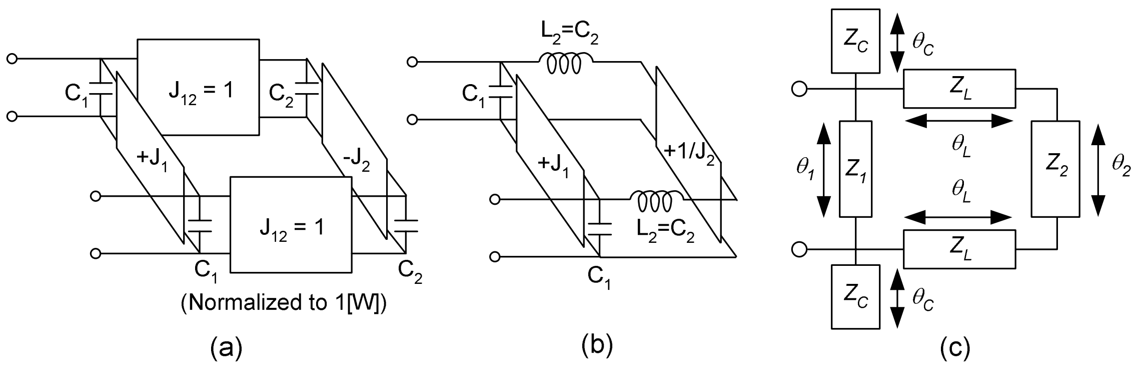

Fig. 2. (a) Symmetrically-folded elliptic-function LPF,
(b) Transformed circuit of (a) with the aide of the equivalences in Figs. 3(a) and (b),
(c) Proposed elliptic-function LPF with a ring-resonator and open-circuited stubs.
(Realization of (b) as a distributed-element circuit.)

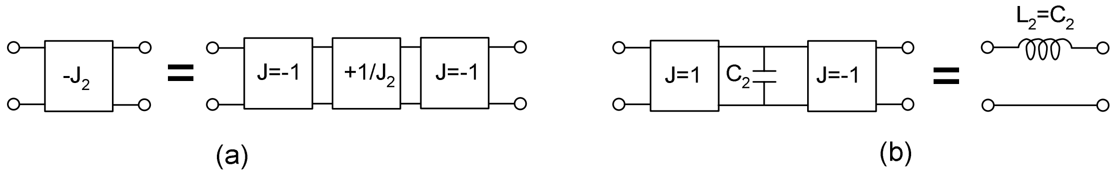

Fig. 3. (a) Equivalence between a negative J-inverter and a cascade of three J-inverters, (b) Equivalence between a shunt capacitor with J-inverters and a series inductor.

III. MICROSTRIP-LINE ELLIPTIC-FUNCTION LOW-PASS FILTER WITH A RING-RESONATOR

Fig. 4 shows a photograph of a fabricated microstrip-line elliptic-function LPF with the ring-resonator, where conventional LC-ladder LPFs [2] are added to the ring-resonator section for attenuation at higher frequencies. The whole circuit is fabricated on three separate alumina substrates with their relative permittivity $\varepsilon_r = 9.5$, where the substrates are connected by bonding wires and via-holes are placed around the ring resonator in order to suppress unwanted couplings between the lines. Figs. 5(a) and (b) show its S-parameters, where the desired TZ is successively realized by the ring-resonator section, and attenuation of more than 60 [dB] is obtained up to the 2nd-harmonic frequency by the LC-ladder LPFs. Some discrepancies in attenuation characteristics are mainly due to errors in the estimation of dielectric permittivity and conductor losses in the design.

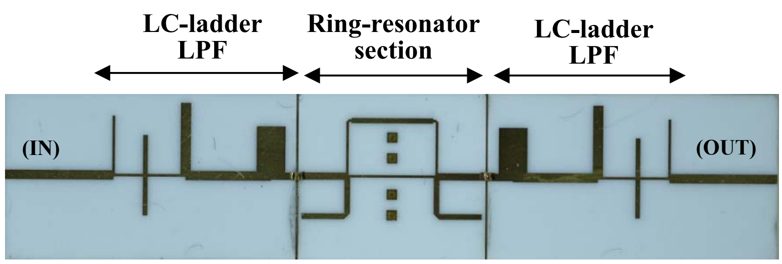

Fig. 4. Photograph of a fabricated microstrip-line elliptic-function LPF. (Fabricated on three separate substrates and wire-bonded.)

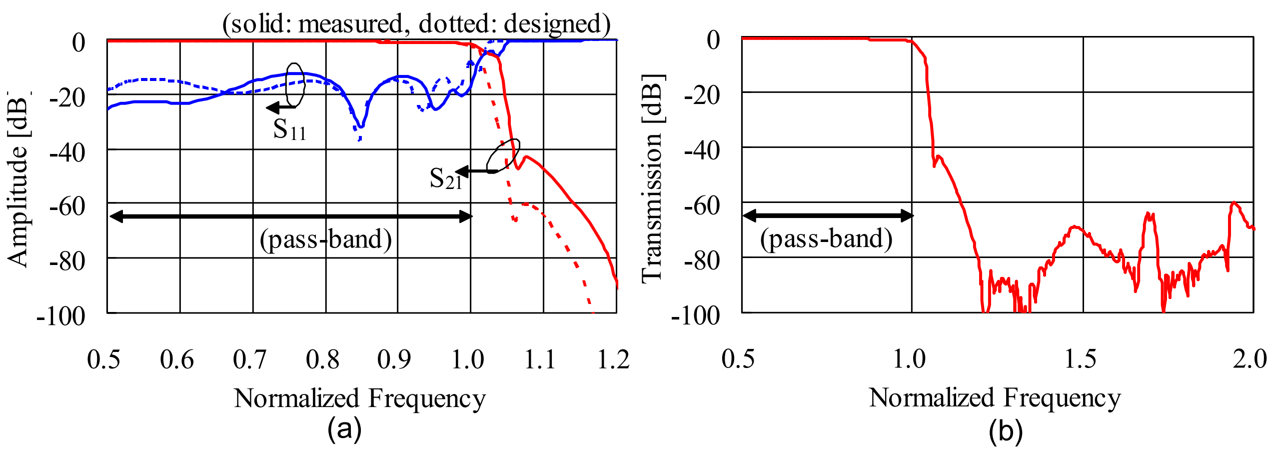

Fig. 5. S-parameters of the microstrip-line elliptic-function LPF in Fig. 4, (a) narrow-band characteristics, (b) wide-band measured transmission characteristics.

IV. CONCLUSIONS

This paper has proposed a novel elliptic-function LPF, where the transmission zero can be realized by a ring-resonator with open-circuited stubs. It is based on the equivalence between the ring-resonator section and a symmetrically-folded elliptic-function. The LPF can eliminate the coupled-lines in conventional elliptic-function LPFs, and results in simplified design and fabrication. It can be applicable for the reduction of spurious spectra in RF active modules.

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