Low-Spurious Coaxial-Line Bandpass Filter with Saucer-Loaded Stepped-Impedance Resonators

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ABSTRACT

A low-spurious coaxial-line bandpass filter (BPF) with saucer-loaded stepped-impedance resonators (**SAUSIRs**) has been developed. The SAUSIR consists of a conventional stepped-impedance resonator (SIR) and a thin metal saucer loaded in the SIR to controll higher-order resonant frequencies of the resonator. By adjusting the positions of the saucers in SAUSIRs, higher-order resonant frequencies of the SAUSIRs in BPF can be scattered in frequency domain without shifting dominant resonant frequency, which results in suppression of spurious responses of the BPF for wide frequency range.

A fabricated 4-stage coaxial-line L-band BPF with SAUSIRs has realized spurious responses less than –50 dB up to about 10 f_0, where f_0 is the center frequency of the BPF.

INTRODUCTION

A distributed-element microwave bandpass filter (BPF) usually suffers from out-of-band spurious responses due to higher-order resonances of distributed-element resonators in the filter. For examples, a BPF with half-wavelength resonators suffers from the second-harmonic spurious response, and the one with quarter-wavelength resonators does the third-harmonic one. To overcome the problem, some kinds of methods have been reported, such as adding a low-pass filter and employing stepped-impedance resonators (SIRs) in the BPF [1]. The former can suppress the spurious responses very easily, but the insertion of the low-pass filter makes the size of the filter much larger.

On the other hand, SIR consists of a cascade of low- and high-impedance transmission lines, and it can make its second-order resonant frequency as high as about 5 f_0, where f_0 is dominant resonant frequency, with physically realizable impedance ratio K of the transmission lines in the SIR [2]. As a result, SIR can suppress the spurious responses of the BPF smartly for wide frequency band below the second-order resonant frequency. However, when suppressing the spurious responses for even upper frequencies, larger value of K is needed [1]. Recently, $K > 25$ with microstrip lines in multi-layer substrate has been realized in [3], where out-of-band spurious responses of a BPF have been suppressed less than –40 dB up to the frequency of about 8 f_0. However, the multi-layer structure suffers from more complexity of the circuit and higher manufacturing cost.

In this paper, a novel structure of coaxial-line SIR named saucer-loaded SIR (**SAUSIR**) has been proposed. In SAUSIR, a thin metal saucer is loaded to a conventional SIR for adjusting its higher-order resonant frequencies without shifting its dominant resonant frequency. By employing SAUSIRs in a coaxial-line BPF and by scattering their higher-order resonant frequencies in frequency domain, the spurious responses of the BPF can be suppressed significantly for wide frequency band.

In our study, a prototype 4-stage coaxial-line L-band BPF with SAUSIRs has been fabricated based on mode-matching analysis [4], and excellent performances of spurious responses less than –50 dB below the frequency of about 10 f_0 and in-band transmission loss less than –0.2 dB have been obtained. The BPF is suitable for mass production,

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since it is made of low-cost aluminum cylinder, brass, low-cost dielectric material, and commercially available SMA connectors.

SAUCER-LOADED STEPPED-IMPEDANCE RESONATOR

Fig. 1 shows the circuit topologies of coaxial-line BPFs with conventional SIRs and with newly proposed SAUSIRs. SAUSIR can be constructed by simply adding a thin metal plate to a conventional SIR, which can be seen as a low-impedance transmission line with infinitesimal electrical-length at dominant resonant frequency of the SAUSIR and its effect can be ignored at the frequency. On the other hand, at higher frequencies, it acts as a shunt capacitor and controlls the higher-order resonant frequencies of the SIR. Fig. 2 shows a calculated example of the dominant and the 2nd-order resonant frequencies of a SAUSIR as a function of the position of the metal saucer. As can be seen, only the 2nd-order resonant frequency can be controlled effectively in SAUSIR.

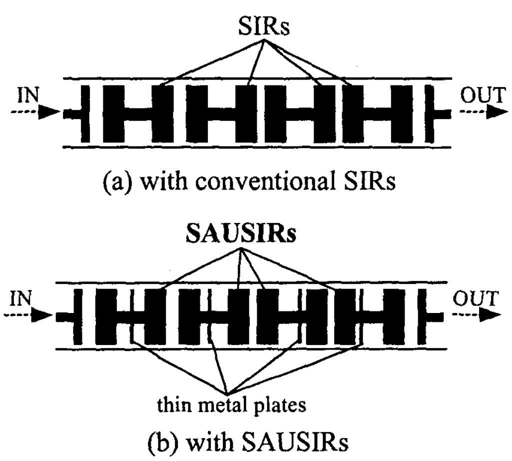

Fig. 1 Coaxial-line bandpass filters

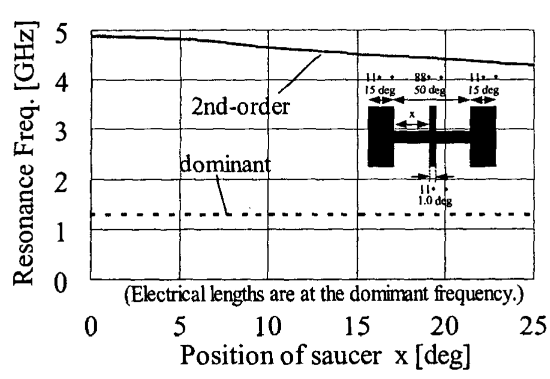

Fig. 2 Resonant frequencies of SAUSIR

PROTOTYPE COAXIAL-LINE BPF WITH "SAUSIRS"

Fig. 3 shows a photograph of a prototype coaxial-line 4-stage L-band BPF with SAUSIRS, where SAUSIRs are employed at the 1st- and 4th-stage resonators. Outer conductor of the BPF is made of low-cost aluminum cylinder, and inner ones are made of brass plated with silver. The resonators are supported by dielectric materials (Teflon) which also act as gap capacitors. This BPF has been fabricated by replacing the 1st- and 4th-SIRs with SAUSIRs in a conventional BPF with only SIRs.

Fig. 4 shows the higher-order resonant frequencies of SIRs/SAUSIRs in the conventional BPF and newly developed BPF with SAUSIRs. In the former, the 1st/4th and 2nd/3rd SIRs have common higher-order resonant frequencies, which causes spurious responses especially at the common resonant frequency of the outer 1st/4th SIRs. On the other hand, by replacing the SIRs with SAUSIRs, the higher-order frequencies are scattered in frequency domain. Fig. 5 shows the measured transmission responses of the BPF with SAUSIRs and the conventional one without SAUSIRs. As can be seen from the figure, the maximum spurious response level has been improved to be less than –50 dB up to the frequency of about 10 f_0 by the SAUSIRs, where f_0 is the center frequency of the BPF. Fig. 6 shows the measured transmission response of BPF with SAUSIRs and the one calculated by mode-matching analysis [4], which agree well each other for the whole frequency range. In the mode-matching analysis, whole structure of the BPF except the connectors at both ends has been taken into account, and has been analyzed as a cascade of coaxial-line and circular waveguide sections.

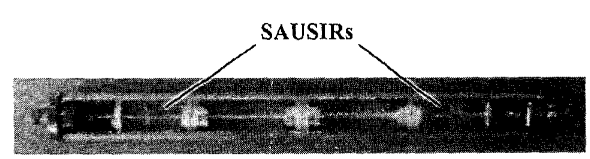

Fig. 3 Photograph of prototype L-band coaxial-line BPF

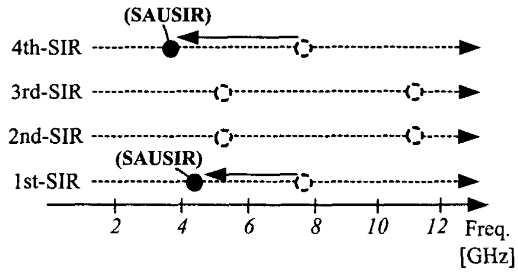

Fig. 4 Higher-order resonant frequencies of resonators in the BPF
(○ : of SIRs, ● : of SAUSIRs)

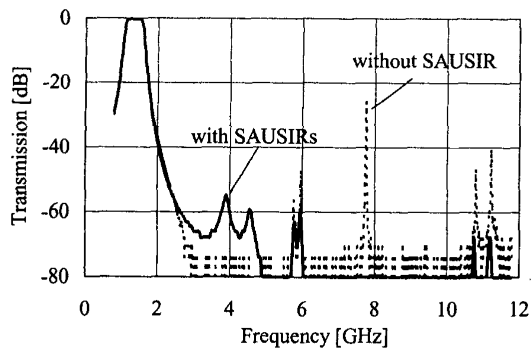

Fig. 5 Measured transmission responses of the BPFs

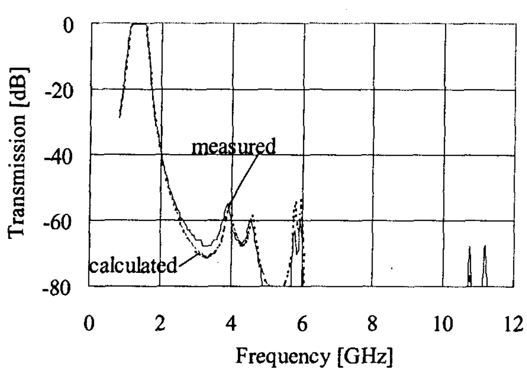

Fig. 6 Measured and calculated responses of the BPF with SAUSIRs

CONCLUSION

A low-spurious coaxial-line bandpass filter (BPF) with SAUSIRs (saucer-loaded stepped-impedance resonators) has been developed. The SAUSIR can be constructed by simply adding a thin metal plate to a conventional coaxial-line SIR, and it can controll the higher-order resonant frequencies of the SIR without shifting its dominant resonant frequency. By employing SAUSIRS in BPF and by scattering their higher-order resonant frequencies in frequency domain each other, spurious responses of the BPF can be suppressed significantly for wide frequency band. A fabricated 4-stage coaxial-line L-band BPF with SAUSIRs has realized less than –50dB spurious responses up to $10f_0$, where f_0 is center frequency of the BPF.

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