Selective Tuneable Active Filter with Gain Using Active Impedance Profile Technique

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Abstract — This paper deals with a novel approach for the design of microwave filters. This approach uses the Active Impedance Profile (AIF) technique and can be considered as an extension of the classical loss compensation method with negative resistances. This technique takes benefit of the adequate imaginary part of an active one-port to control the bandwidth and selectivity of a passive filter response, while the real part simultaneously compensates for the losses in the passbands. We first explain this method and then, we apply it to the design of a selective tuneable band-pass filter.

I. INTRODUCTION

In the past years, passive filter structures solutions were mostly of the volumic type. The main drawback of volumic filters is too important dimensions. This problem can be definitely reduced if planar technologies are considered. However, with these technologies, all the passive topologies leads to lossy responses, avoiding highly selective characteristics. Since several years, active filtering solutions have become promising for the design of integrated planar circuits [1] [2]. Using active techniques, improvements classically rely on loss compensation in the passbands, but also on size and weight reductions. Recently, request for new capabilities and applications for telecommunication systems have imposed better performances for example for the front-end receivers. The most popular proposed solutions, generally consist in compensating the filter losses, either with amplifiers, or with negative resistance circuits. With this approach, the objective performance is to design pure negative resistance circuits, with a minimum associated parasitic imaginary impedance. We here explain how to take benefit of the associated imaginary part of the active chips on the filter response shape. We apply the Active Impedance Profile (AIP) method to the design of a selective tuneable band-pass filter. In a first step, we explain the method and show the role of the imaginary part of the active circuit on the response. We then apply this method to the design of a selective band-pass filter using a GaAs process and show measurement results.

II. ACTIVE IMPEDANCE PROFILE PRINCIPLE

Generally, compensation techniques just focus on a mean of compensating losses introduced by passive parts of a circuit. In most cases, the objective is then to improve the transmission level of the filters in the passbands.

The technique then consists either on designing directly perfect active elements (inductances [3] or capacitances) by means of gyrators (or NICs), or on compensating for losses thanks to circuits simulating negative resistance behaviour. In planar passive filters, depending on the technology used, the most degrading elements are either microstrip line -based resonators or integrated spiral inductors. In both cases, the simplest way to compensate for the losses in then to connect in series a negative resistance circuit.

With the Active Impedance Profile technique, an adequate active one-port circuit is added to a passive filter. This active circuit presents a complex impedance $Z(f) = R(f) + jX(f)$ for which the imaginary part contributes to a significant improvement of the filter response. The objective is then to determine the characteristics of the active one-port in terms of real and imaginary parts:

1) the value of the real part to strictly compensate for the losses of the passive filter in the pass-band,
2) the value of the imaginary part to set the central frequency of the global filter (see Fig. 1) [6],
3) the slope of the imaginary part in a given frequency band around the central frequency to adjust the filter bandwidth and selectivity.

As an example, we consider here a bandpass filter based on a $\frac{\lambda_0}{2}$ resonator connected at its input and output through $\frac{\lambda_0}{4}$ coupled lines (Fig. 2). The filter response presents insertion losses at its central frequency.

![Fig. 1. Active Impedance Profile principle](image-url)
III. APPLICATION OF THE AIP PRINCIPLE

We now apply this technique to the design of a selective bandpass filter. The procedure is described in three steps.

A. Starting point of the design

The objective is to realise a bandpass filter around 15 GHz with a 50 MHz-bandwidth. The initial passive filter is shown in Fig. 5.

The passive filter response is around 35 GHz, with a 4GHz bandwidth and insertion losses around -7 dB.

B. AIP characteristics extraction

The next step is to find, for each frequency point, the real and imaginary parts of the AIP circuit to connect to the passive parts (at point A) to carry out the desired response of the global filter. This impedance is shown in Fig. 6.

C. AIP design

In a first step, we must determine which topologies are able to realise the desired impedance behaviour. In general, these topologies are based on negative resistance topologies [4], [5]. For our case, the active circuit (Fig. 7) consists of a common-source transistor with series feedback.

For this filter topology, an increase of the value of the imaginary part of the AIP involves a centre frequency decrease. An increase of the slope leads to a narrower bandwidth.
Fig. 7. Active circuit topology

The real part is realised through the LC-shunt tank and the imaginary part through the other elements. A diode is added in series to shift the value of the imaginary part and then to influence the global filter response.

D. Active filter layout

The two parts (active and passive) are associated in a single chip whose dimensions are 2*1.5 mm² (Fig. 8). Simulation results are shown in Fig. 9. This filter achieves a central frequency at 14.62 GHz with 0 dB of insertion losses, a bandwidth of 60 MHz and an isolation at central frequency around 42 dB.

Fig. 8. Active filter layout

Fig. 9. Simulated results

III. MEASUREMENT RESULTS

The first measurement results have been obtained with the scheduled bias voltages. A comparison between measurements and simulations is shown in Fig. 10. As can be shown, in spite of a frequency shift of 230 MHz, measurements are in good agreement with simulations. There are no losses in the passbands at the centre frequency. The passband is 60 MHz wide.

In a second step, diode bias voltage is tuned to show the effect of the imaginary part of the active circuit on the response. Bias voltages of the transistor are adjusted to maintain the level of the response. Best measurements obtained are shown in Fig. 11.

Fig. 10. Comparison between simulations and measurements

Fig. 11. Measured tuned response of the filter

Measurements show the expected tuneability of the central frequency provided by the imaginary part of the active circuit. The response is tuneable on a 850 MHz wide frequency range. Gain at central frequency is between 2.2 and 3.6 dB. Bandwidth is around 55 MHz. All these results are in perfect agreement with simulations.
IV. CONCLUSION

The AIP technique is derived from the classical loss compensation approach based upon the use of circuits simulating a negative resistance. By appropriately taking benefit of the associated imaginary part of such circuits, we have shown the effects and improvements performed on the bandwidth and selectivity of a one-pole distributed passive filter response. With this technique, we have designed a tuneable filter with gain in the passband (between 2.2 dB and 3.6 dB) and a narrow bandwidth (55 MHz).

REFERENCES