Active Varactor Tunable Bandpass Filter

S. R. Chandler, I. C. Hunter, *Member, IEEE*, and J. G. Gardiner

Abstract—**A microstrip active varactor tunable bandpass filter is presented. The filter is based upon the negative resistance method using a microstrip combline network. A 1.8-GHz, two-pole device with a bandwidth of 2% was constructed. 0.6 octave tuning with significant improvement in passband performance was achieved compared with its passive counterpart.**

I. Introduction

A NUMBER of papers have recently been published on microwave active filters [1]–[4] with the view to an approach for MMIC filter implementation. Earlier work [1], [2] addresses the use of negative resistance in tunable end coupled microstrip filters. The work presented in this letter utilizes a microstrip combline topology to produce a filter with an enhanced tuning range and of a more compact size enabling the possibility for MMIC fabrication for frequencies from mid C-band upwards. The filter uses Marconi DC4371A varactors with a quality factor of 55 at 1.8 GHz and –4 volts bias. A major drawback of using varactors in filters is their inherently low Q at microwave frequencies thus giving narrowband filters an intrinsically high-insertion loss. By introducing negative resistance into the filter by the use of active devices it is possible to compensate the losses introduced by both the varactor and those that are associated with the filter. The aim of the negative resistance is to restore the Q of the resonators whilst ensuring system stability.

II. Synthesis of Filter

Earlier work by Hunter and Rhodes [5] described an approach to the design of varactor tunable combline filters. A computer program has been written to calculate the mutual and self capacitances for multiple coupled lines of unequal width on microstrip [6], [7]. Additional cross couplings between nonadjacent lines were calculated and included in the final analysis on Super-Compact. The effect of this cross coupling was noticeable as an additional transmission zero appearing close to the passband on the high side of the filter.

The negative resistance is generated using an AVANTEK AT41435 silicon bipolar transistor in common collector configuration with a resonant circuit connected to its base. This has the effect of generating negative resistance within the tuning range of the filter whilst ensuring low frequency and high-frequency stability. This negative resistance is then connected to the filter at the node between the tuning varactor and the coupling capacitor to ground.

Manuscript received october 26, 1992.
The authors are with the Telecommunications Research Group, Department of Electronic and Electrical Engineering, University of Bradford, Bradford, West Yorkshire BD7 1DP, England.
IEEE Log Number 9207210.

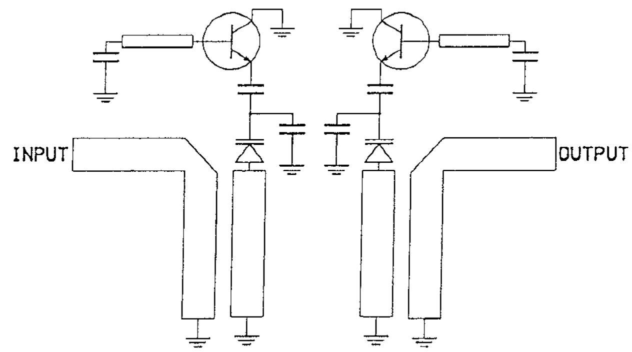

Fig. 1. Schematic view of varactor tunable combline filter.

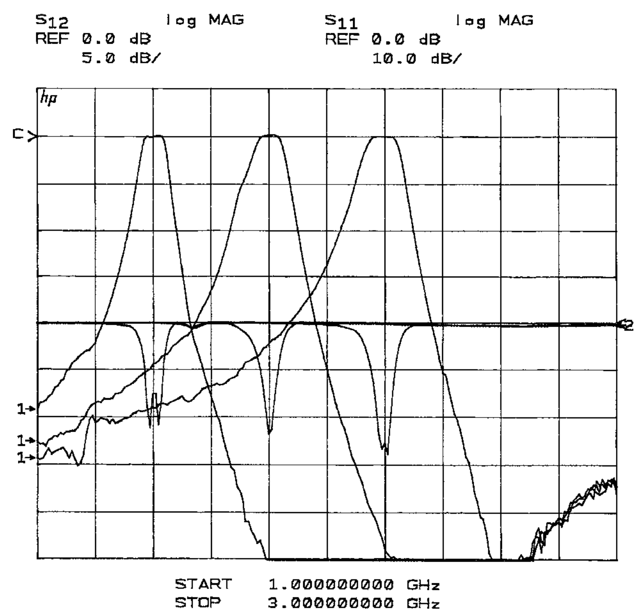

Fig. 2. Performance of varactor tunable active filter.

A two pole 2% bandwidth 0.01-dB ripple Chebychev filter with a center frequency of 1.8 GHz was constructed on 0.06" RT Duroid with an ε_r of 2.55 (Fig. 1).

III. Results

The measured performance of this filter is shown in Fig. 2. A tuning range of 1.4 GHz to 2.2 GHz with a return loss of better than −15 dB and a flat zero-insertion loss passband was recorded. For comparison, Fig. 3 shows the filter response with the active elements isolated. The use of such a filter in a microwave subsystem is dependant upon nonlinear effects such as the 1-dB compression point and in band third-order intercept point. These parameters were measured for both the active and

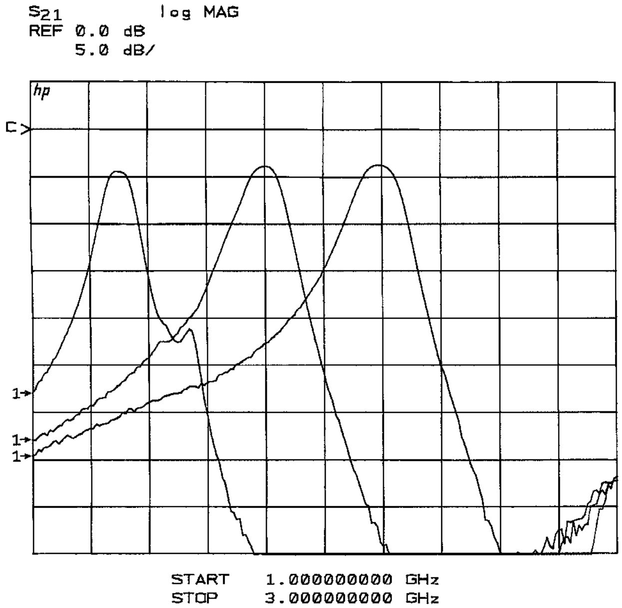

Fig. 3. Performance of varactor tunable nonactive filter.

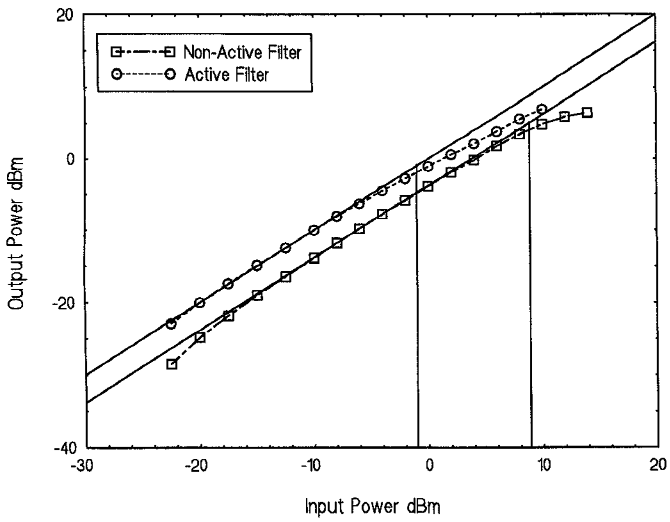

Fig. 4. 1-dB compression curves at 1.8 GHz center frequency for active and nonactive filter.

nonactive filter, the results for the filter at its center frequency of 1.8 GHz are shown in Fig. 4 and Fig. 5, respectively. The in-band third-order input intercept point was measured using two tones 200 kHz apart centered at 1.81 GHz. The noise figure of the active filter is also important within the system and was measured as 6.8 dB at 1.8 GHz.

Measurements across the filters tuning range were taken, these generally showed an improvement in 1-dB compression point and third-order intercept point with increasing center frequency, increasing varactor reverse bias, and a deterioration in measured noise figure.

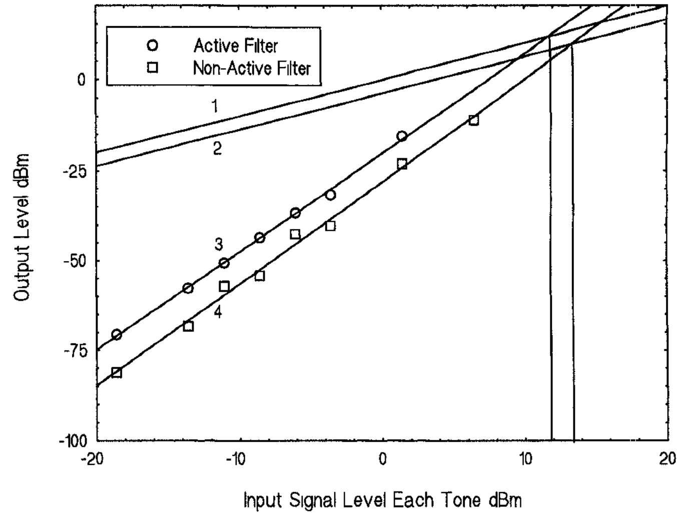

Fig. 5. Two tone third-order input intermodulation curves at 1.8-GHz center frequency for active and nonactive filter. 1) Wanted signal active filter. 2) Wanted signal nonactive filter. 3) Third-order intermodulation products active filter. 4) Third-order intermodulation products nonactive filter.

IV. Conclusion

An active microstrip combline filter has been constructed. This filter is compact, lossless and capable of a large tuning range. The 1-dB compression point and the third-order intercept point are very dependant upon the varactors reverse bias. The noise figure of the filter is frequency dependant and is a function of the insertion loss of the passive filter along with an element of noise being added by the transistors that form the negative resistance generators. The filter being tunable also reduces tolerance problems in its manufacture. The amount of negative resistance being introduced into the filter is also dependant on the transistors bias point thus this parameter can be adjusted to cope with variations in ambient temperature and can also be loosely toleranced.

References

[1] C. Y. Chang and T. Itoh, "Microwave active filters based on coupled negative resistance method," *IEEE Trans. Microwave Theory Tech.*, vol. 38, pp. 1879–1884, Dec. 1990.
[2] H. Trabelsi and C. Cruchon, "A varactor-tuned active microwave bandpass filter," *IEEE Microwave Guided Wave Lett.*, vol. 2, pp. 231–232, June 1992.
[3] S. E. Sussman-Fort, "Design concepts for microwave GaAs FET active filters," *IEEE Trans. Microwave Theory Tech.*, vol. 37, pp. 1418–1424, Sept. 1989.
[4] M. Healy, R. D. Pollard, and C. M. Snowden, "Active filters for MMIC's," in *Proc. 17th European Microwave Conf.*, Rome, Italy, Sept. 1987, pp. 443–447.
[5] I. C. Hunter and J. D. Rhodes, "Electronically tunable microwave bandpass filters," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-30, pp. 1354–1360, Sept. 1982.
[6] R. Garg and I. J. Bahl, "Characteristics of coupled microstrip lines," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-27, pp. 700–705, July 1979.
[7] M. Kirschning and R. H. Jansen, "Accurate wide-range design equations for frequency-dependent characteristic of parallel coupled microstrip lines," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-32, pp. 83–90, Jan. 1984.