AN MMIC ACTIVE FILTER WITH 60-dB REJECTION*

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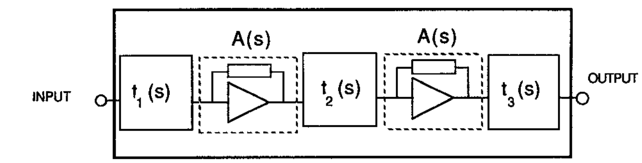
ABSTRACT

The design, fabrication, and characterization of a gallium arsenide (GaAs) monolithic, active, 4-GHz bandpass filter with 60-dB edge-of-band rejection is described herein. A predistorted transfer function is realized by a set of cascaded, lumped, and distributed-element inductance capacitance circuits isolated by two feedback amplifiers. The monolithic microwave integrated circuit consists of two identical 3 x 2-mm GaAs chips.

INTRODUCTION

Wideband microwave filters have a variety of applications in subsystems such as receiver front ends, spectrum demultiplexing, harmonic rejection, and analog signal processing. Traditionally, these filters have been built from resonator elements realized in waveguide, coaxial, strip, and microstrip lines, but with the rapid maturation of monolithic mircrowave integrated circuit (MMIC) technology, miniaturizing and integrating these filters is an attractive possibility [1],[2].

This paper extends the development of an octave-band MMIC active filter [2] by presenting a wideband active MMIC filter in which a 4-GHz predistorted bandpass transfer function [3] with a stopband of 60 dB was realized by the cascade of low-order transfer functions isolated by wideband feedback amplifiers. Predistortion was used to minimize the roundness at the band edge, produced by the low Q of MMIC circuit elements. This design approach has been shown to result in a frequency response that has a lower sensitivity to circuit element tolerances and a potentially higher RF circuit yield than a conventional passive lumped-element circuit [2]. The individual blocks are synthesized by a combination of lumped and distributed circuit elements, and the overall circuit is realized by cascading two identical monolithic chips (see Figure 1).



$$T(s) = t_1(s) \cdot A(s) \cdot t_2(s)\ A(s) \cdot t_3(s)$$

$$t_2(s) = t_1(s) \cdot t_3(s)$$

Figure 1. Cascade Realization of Transfer Function T(s)

DESIGN PROCEDURE

The first step in the design process is synthesizing a transfer function, T(s), that meets the required specifications. Generally, a number of different transfer functions satisfy a given requirement, and an optimum design requires a detailed tradeoff analysis among the candidate circuits. The relevant parameters considered in the tradeoff are:

- MMIC component realizability (capacitance and inductance values, transmission line lengths, etc.);
- Implementation margin between the computed response and the required specifications;
- Frequency response sensitivity to circuit element fabrication and modeling tolerances (evaluated through the RF yield computation);
- Final circuit size.

To arrive at an optimum design, five different circuit topologies were generated and compared. Figures 2 and 3 show the lumped-element circuit diagram and the computed frequency responses respectively, for all five configurations. The low return losses, characteristic of predistorted designs, lead to a relatively high insertion loss in passive circuits which, in this case, is compensated by the gain blocks. The basic differences between the five transfer functions are the passband ripple level, the position

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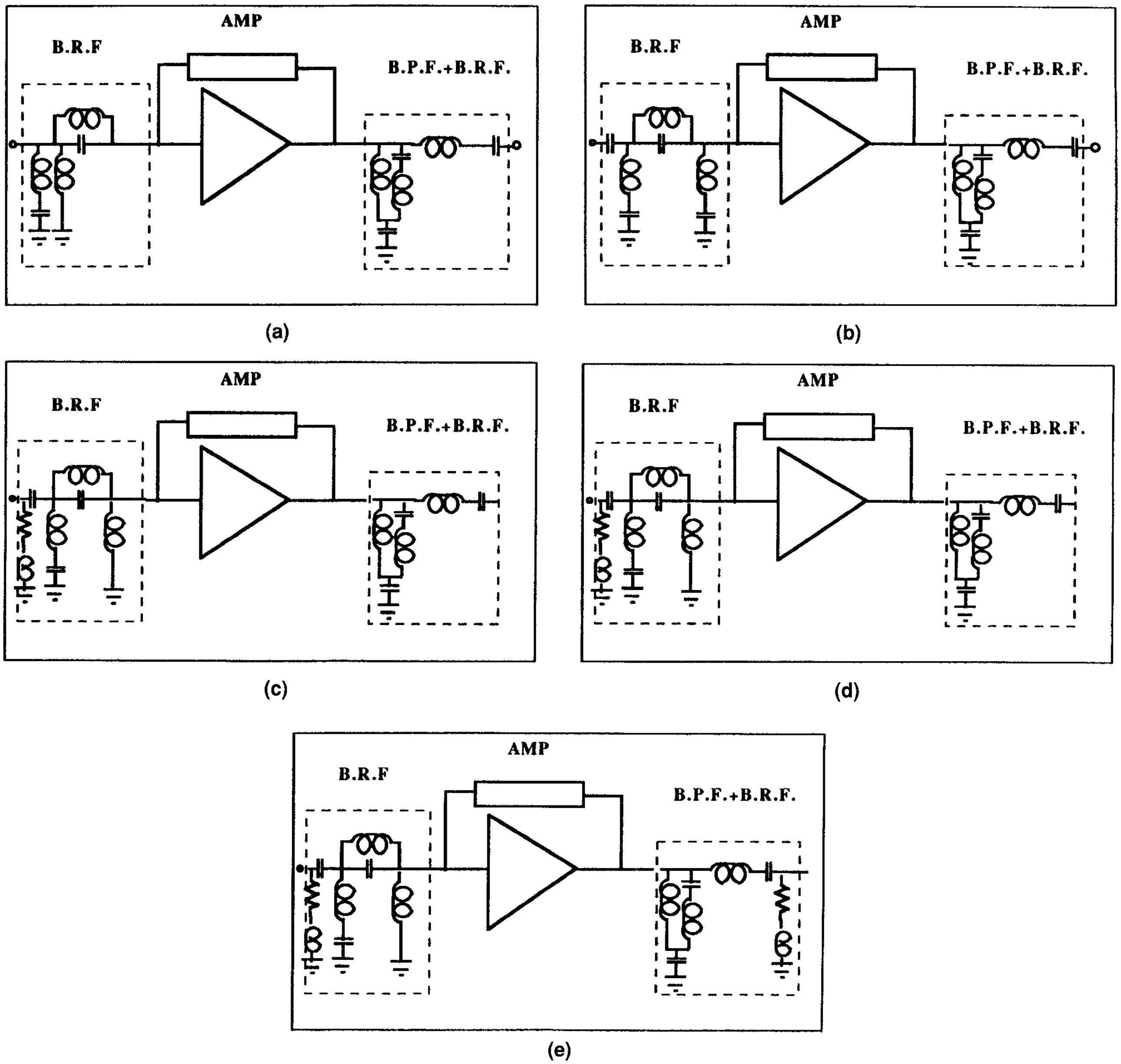

Figure 2. Synthesized Circuit Configurations

of transmission zeros, and the sensitivity to variations in circuit element value. The yield comparison in Figure 4 illustrates the latter. All yield computations were performed using the Monte Carlo method, with assumed element tolerances based on past MMIC fabrication and modeling accuracy history. Only RF performance was considered in the yield determination, and tolerance variations were introduced only in the passive elements. The lower sensitivity of circuit configurations D and E over A, B, and C is evident from their higher RF yield. Based on its superior theoretical yield and lower passband ripple, configuration E was selected for implementation.

MMIC FABRICATION

Figure 5 is a photograph of the fabricated circuit E assembled in a carrier. The inductors were synthesized with different combinations of coupled sections of high-impedance transmission line. The capacitors were made from 2,000-A silicon nitrate films. The amplifier design incorporates a resistive feedback similar to the circuit described by Gupta in Reference 4. The field-effect transistors (FETs) are low-current, 0.5-μm gate length devices fabricated on GaAs substrate, and were designed after those described by Mott in Reference 5. The filter was

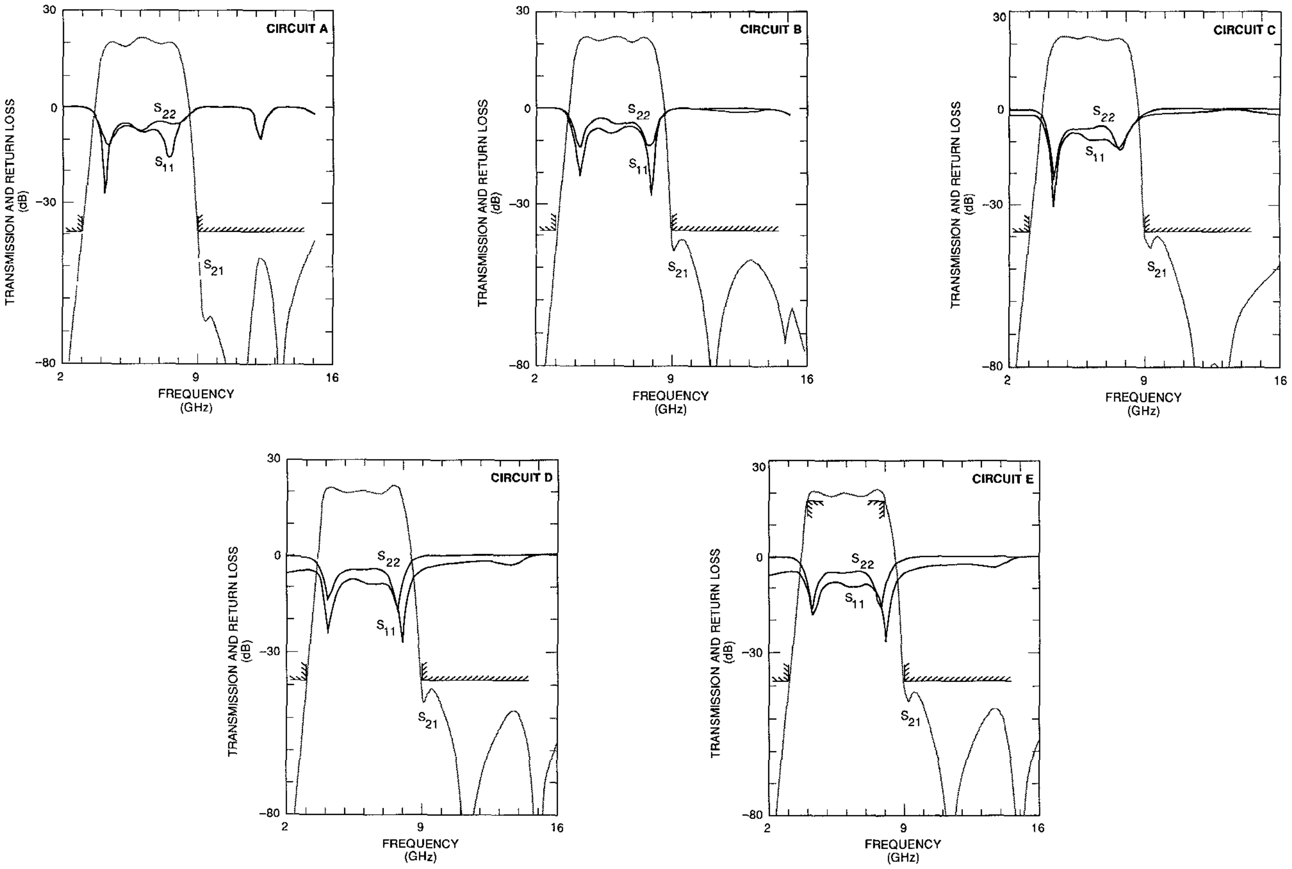

Figure 3. Theoretical Circuit Responses

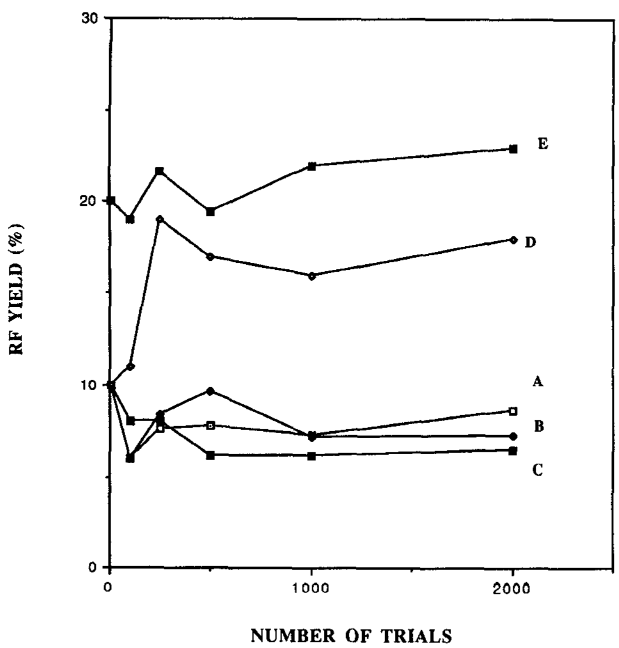

Figure 4. Computed RF Yield Comparison

assembled in a carrier that interfaces with a microstrip-to-coaxial transition, and grounding was provided at both edges of the substrate in order to decrease spurious input-to-output coupling via below-cutoff surface wave modes.

MEASURED PERFORMANCE

Figure 6(a) shows the measured frequency response of a typical unit that passed on-wafer DC probing. The design goal of 60-dB rejection at the skirt edges was realized even though the amplifier was not biased to achieve its highest gain. Note that some gradual reduction in rejection occurred between 12 and 18 GHz. This was found to be caused by spurious coupling between the two microstrip-to-coaxial transitions. Transmission measurements, performed both with the MMIC carrier removed from the test fixture and with the carrier installed but the FETs off, show a similar degradation in isolation (see Figure 6[b]). The gain slope at the band edge suffered some rounding due to a detuning effect in the predistorted return loss zero position while the overall frequency response was approximately 3 percent higher than that predicted for the models. This was due to a phase shortening

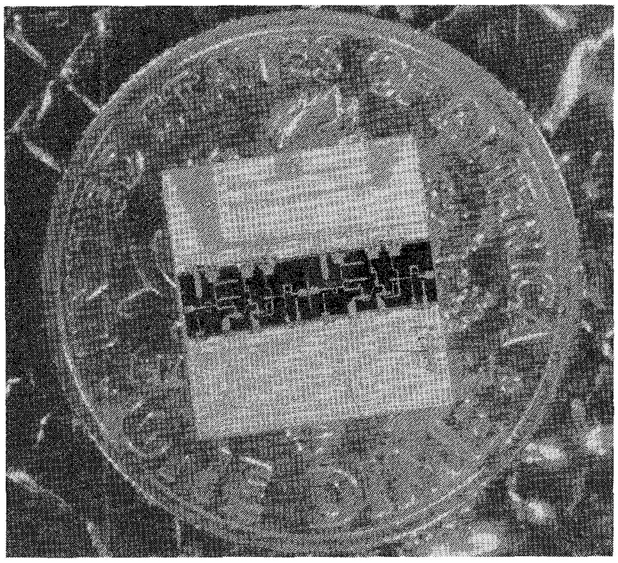

Figure 5. Photograph of the MMIC Filter Circuit Assembled in Carrier

effect caused by a dielectric passivation layer that covered the whole substrate and whose effect could not be accurately predicted by existing CAD models.

CONCLUSIONS

A wideband MMIC active filter with 60-dB rejection has been realized in a design that employs a predistorted, shaped response together with low-order filter sections isolated by feedback amplifiers to decrease circuit response sensitivity. A remarkable advantage of this circuit over other resonator-based implementations is the absence of a second harmonic passband. Only one fabrication cycle was necessary to demonstrate and validate the concept. Small corrections to inductor lengths should bring the center frequency to the prescribed range in a second fabrication cycle.

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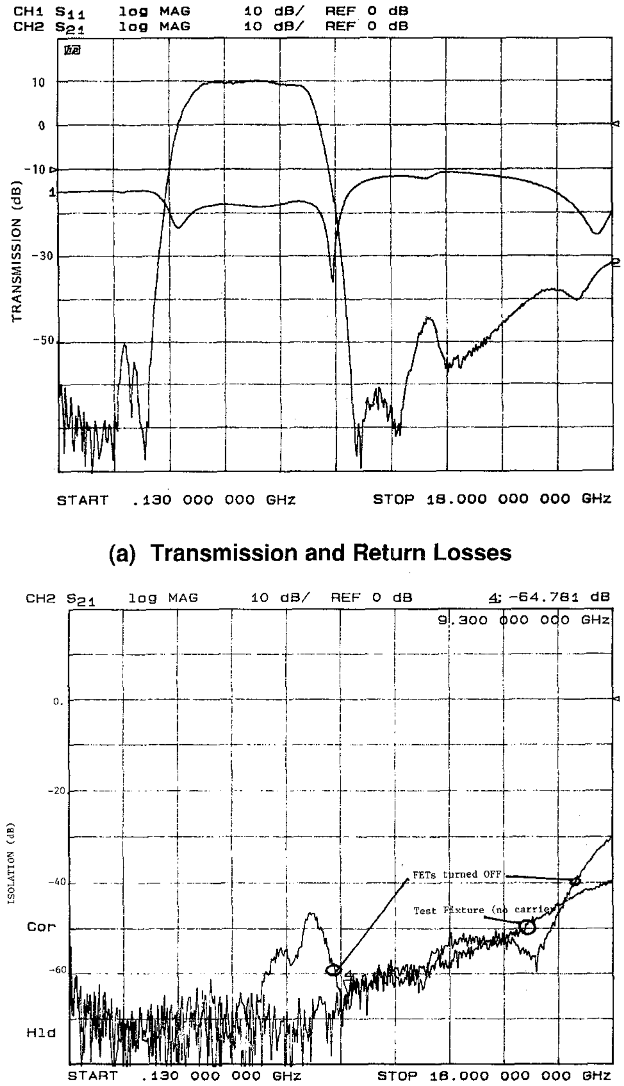

(a) Transmission and Return Losses

(b) Test Fixture Spurious Coupling

Figure 6. MMIC Filter Measurements

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