simultaneously, this approach suggests a possibility of simplifying the original problems into easier subproblems of linear phase FIR. A concrete design method based on the LP-decomposition structure remains for further research.

References


MMIC tunable active notch filter

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Indexing terms: Notch filters, MMIC

A novel microwave notch filter is reported which has a single-stage reflection topology. The identical RLC reflection terminations employ independent voltage-controlled elements. As a result, the Q-factor and notch frequency can be varied. An experimental notch filter, tunable from 2 to 3.5GHz, has been successfully realised using monolithic technology.

Introduction: Notch filters are widely used in communications and radar applications, where a band of unwanted frequencies must be rejected from a signal, e.g. the unwanted frequency components could be due to the transmission of pilot tones, local oscillator leakage, adjacent or co-channel interference or jamming signals.

The use of monolithic microwave integrated circuit (MMIC) technology is becoming more widespread, owing to its size, mass and yield advantages over the more traditional hybrid microwave integrated circuit technology. In certain applications it may be necessary to control the Q-factor and frequency of the transmission nulls. Therefore, some form of tuning mechanism is required. In MMIC technology, a great deal of work has recently been undertaken to model variable capacitors i.e. varactor diodes [1], variable resistors i.e. cold-FETs [2], and variable inductors i.e. tunable active inductors (TAIs) [3]. These voltage controlled elements have been successfully deployed in a range of MMIC applications [3–7].

The design of a novel MMIC notch filter is presented in this Letter. Here, a single-stage reflection topology is used, as illustrated in Fig. 1. Two identical RLC series-tuned circuit reflection terminations employ independent voltage-controlled elements. At the resonant frequency, the termination impedance is resistive, with its value controlled primarily by the cold-FET. As the termination resistance approaches the impedance of the directional coupler (i.e. 50Ω), the transmission null deepens. The frequency of this null can be varied by controlling the value of the variable capacitance and/or inductance. With the use of TAI’s, its Q factor and, therefore, that of the reflection termination and the overall filter can be controlled. This has previously been demonstrated with an MMIC tunable bandpass filter [3].

MMC realization: Since a wide notch frequency tuning range was required, a Lange coupler was chosen, as this type of 3dB quadrature coupler maintains its high level of performance across a bandwidth of more than one octave. Also, this coupler can be easily folded, thus reducing the amount of wasted area and greatly improving the aspect ratio of the chip. Interdigitated planar Schottky junction varactor diodes were realised using standard ion-implanted 0.5μm MESFETs, by connecting the drain and source terminations together to form the cathode electrode [1]. Similarly, the cold-FETs were implemented using standard MESFETs [2]. The TAI’s were designed using a totem-pole arrangement of standard MESFETs. The topology and operation of the TAI’s has been previously reported in detail [3]. Finally, the varactor diodes, cold-FETs and TAI’s were sandwiched between large value DC blocking capacitors, in order to maintain independent voltage control.

A microphotograph of the complete, single-stage, MMIC notch filter is shown in Fig. 2, having dimensions of 4 × 3mm². The MMIC was fabricated at the GEC-Marconi foundry, using their commercial F20 foundry process.

Measured results: The notch filter was tuned to give a deep transmission null that could be placed at any location across a wide frequency range. The resulting measured insertion loss performance of the filter is shown in Fig. 3. Transmission nulls are shown at arbitrary frequencies of ~2, 2.5, 3 and 3.5GHz. These nulls have extremely high Q values, with depths of >50dB, and without the use of off-chip resonators. The close-in out-of-band rejection characteristics are also excellent, as there are no discrete spiral inductors in the filter. Finally, since a reflection topology has been used with Lange couplers, a good return loss performance is inherent over a wide frequency range. In practice, the worst case measured values of input and output return losses were better than 15dB.
Discussion: When standard foundry library elements are employed in the design of MMICs it is found that significant parasitic series resistance variations are inherent with interdigitated varactor diodes. Conversely, significant parasitic shunt capacitive reactance variations are found with cold-FETs. As a result, there could be considerable interactions taking place when the varactor diodes, cold-FETs and TAs are initially tuned. However, if mesa-type varactor diodes are used and the cold-FETs are replaced by pin diodes, requiring the use of more expensive foundry processing, these interactions would be minimal.

A more compact filter could be implemented by replacing the directional coupler with an active circulator. Moreover, only a single reflection termination would be required. In addition, the TA1 could be replaced with a spiral inductor and the varactor diode could be replaced with a tunable active capacitor (TAC) [4]. This approach has the advantages of a simpler topology and reduced power consumption. Also, since the amount of negative resistance associated with the TAC can exceed the combined losses in a reflection termination, the same topology can be transformed from a notch filter into a very high Q bandpass filter. This bandpass filter would then exhibit the same excellent return loss performance, which is currently one of the main limitations of conventional active filter designs [3, 4].

Conclusions: A novel microwave tunable active notch filter has been designed, fabricated and tested. The proof-of-concept notch filter consists of a single-stage reflection topology, employing completely tunable RLC elements in the reflection terminations. The measured performance of the experimental filter, implemented using monolithic technology, has demonstrated a deep transmission null, >50dB, which can be located at any arbitrary frequency between 2 and 3.5GHz. The close-in out-of-band rejection and return loss performances of the filter are excellent. Finally, a number of design modifications are proposed, which may provide some improvements in the overall performance.

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References

Canonical structure for systematic rate k/n convolutional encoders and its application to turbo codes

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Indexing terms: Turbo codes, Convolutional codes

Systematic recursive convolutional encoders have been shown to play a crucial role in the design and implementation of parallel concatenated codes (‘turbo codes’). The authors present a canonical structure of minimal linear systematic rate k/n encoders and show how to use it in the search for good constituent codes of parallel concatenated codes.

Introduction: The algebraic structure of convolutional codes has been described in a basic paper [1]. Recently, equivalent non-systematic encoders and a particular structure of systematic recursive rate 1/n convolutional encoders have been compared in [2], with the aim of using systematic codes as constituent codes (CCs) of parallel concatenated convolutional codes (PCCCs), also known as ‘turbo codes’. The importance for a CC of turbo codes to be both systematic (for decoding simplicity) and recursive (to maximise the interleaver gain) has been assessed in [3], where design guidelines were also proposed for rate 1/n CCs. In [4] the results of [3] were extended to rate k/n CCs and tables of “optimum” CCs presented. In this Letter we propose a canonical structure of minimal linear systematic recursive encoders for rate k/n convolutional codes and use it in the search of “optimum” rate 2/3 CCs to be embedded in rate 1/2 turbo codes. The performance of the obtained turbo codes is also shown.

Encoders for binary convolutional codes: A time-invariant binary convolutional code C of rate k/n is a collection of bi-infinite sequences e ∈ C ⊆ {0, 1}^∞ forming a group. An encoder E = (U, Σ, Y, g, f) for C is defined by an input set U = U^∞, an output set Y = Y^∞, a finite-state set Σ, a state update function g: Σ × U → Σ, and an output function f: Σ × U → Y. Starting from time zero, when it is in the zero state, E processes an unconstrained semi-infinite input sequence u ∈ (Z)^∞. An input-output sequence pair (u, y) is admissible in E if there exists a state sequence s such that (s_t = g(s_{t−1}, u_t) and y_t = f(s_t, u_t), for all t ∈ Z. Let E denote the set of all admissible pairs (u, y): the set of all output sequences y appearing in E must be the subcode C ⊆ C containing all code sequences of C that are identically zero before time zero. For any s ∈ Σ, and any u ∈ U, we can introduce the triplet (s, y, z) and the quadruple (s, u, y, z), where y = f(s, u) and z = g(s, u). The two sets of all 2^2 triplets and quadruples are the state-output trellis section T and the input-state-output trellis section T, respectively. In this Letter, an encoder is systematic if u_t is the projection of y_t on the first k components. A systematic encoder cannot be catastrophic. In [5] it has been proved that the code C has a well defined minimal state group, that does not depend on the encoders that generate C. An encoder E for C is minimal if its space state Σ has the same size as the state group of C. A minimal encoder is never catastrophic. All minimal encoders have the same state-output trellis section; they differ only in the input-state-output trellis section.