Wideband Class-B Power Amplifiers

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Abstract

Wideband Class-B power amplifier is required in Modern communication systems. The bandwidth limitation of Class-B Power amplifier is generally caused by the narrow band 2^{nd} harmonic short. In this thesis the methods of 2^{nd} harmonic manipulation in Class-B power amplifier are discussed.

In the beginning, the current and voltage waveforms at output of the amplifier are analyzed, and a series of load configurations which can give good performance in Class-B power amplifier is given.

In single-ended topology the traditional 2^{nd} harmonic short networks are band limited and interaction between fundamental impedance and 2^{nd} harmonic impedance limited the performance of short networks. Introducing varactors into the short networks the bandwidth of amplifier is extended. Performance of commercial varactor is restricted by the breakdown voltage and package parasitic. A 32% relative bandwidth Class-B power amplifier is realized with the 90 V break down voltage varactors from the Aeroflex central frequency of the amplifier is 1 GHz, the drain efficiency is above 65% over the frequency band.

In differential topology the fundamental signal and 2^{nd} harmonic are isolated, which provides convenience for wideband design. In practical design the bandwidth limitation is generally caused by the non-idea transformer in fundamental matching, compensation capacitors are required at primary of transformer. In low power condition, the 2^{nd} harmonic short bandwidth can be extended by using the coupling between primary inductors. Two loops structure is applied in this case. In high power design, the 2^{nd} harmonic is shorted though the large compensation capacitors. One loop structure is applied in this condition. In simulation result these structures can provide 50% to 70% relative bandwidth, which indicates their potential in wideband Class-B design.

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5.1. Conclusion

In this work several topologies for Class-B power amplifiers are discussed. It had been shown that with a suitable setting of the fundamental and 2^{nd} harmonic impedance over the frequency band, wideband performance could be achieved. Two structures are considered in this work.

The single-ended topology is easy to apply, but its wideband performance is affected by the interaction between the fundamental load and 2^{nd} harmonic impedance. The candidates for a 2^{nd} harmonic short network QWTL and series resonator are bandwidth limited. Varactors have been introduced to extend the bandwidth. The tuning ratio of varactor is restricted by the supply voltage of the amplifier. The tuning range of the quarter wave frequency and characteristic impedance of tunable QWTL are constrained by the capacitance variation of the varactors. All these factors limited the achievable bandwidth in a power amplifier. Also package parasitic of transistor and varactor reduce the bandwidth performance of the 2^{nd} harmonic short network. In the end a 32% bandwidth power amplifier has been designed and realized.

The differential topology can separate the fundamental and 2^{nd} harmonic signals. This proves to be a big advantage for wideband design. In the differential topology the balun is critical to the performance. The fundamental matching and 2^{nd} harmonic short in differential topology using a non-ideal balun is discussed. Based on these conclusions bondwire based baluns are investigated to realize the function. The bandwidth performances of several bondwire configurations are discussed.

In practical wideband designs, the 2^{nd} harmonic impedance cannot be manipulated to zero over the frequency band. Therefore, reducing the real part of 2^{nd} harmonic impedance and manipulating its imagery part is a wise thing to do in wideband Class-B power amplifier design.

5.2. Recommendation

5.2.1. Matching Network Design

In chapter 2 we achieved the conclusion, that in order to get good performance the fundamental reactance should track with the 2^{nd} harmonic impedance. In this work the design of matching network is generally based on the requirement of fundamental resistance, the variation of the reactance is not considered specifically. By carefully adjusting the parameters of the components and change the structure of the matching network, better performance might be possible to achieve.

5.2.2. Tunable QWTL

In tunable single-ended power amplifier, the bandwidth and performance of amplifier is limited by the breakdown voltage and capacitance of the varactor. If higher breakdown and larger capacitance varactors are available, better tunable power amplifier can be made.

In this work the tunable QWTL is used to short circuit the 2^{nd} harmonic. There are still other ways to use QWTL in power amplifier. For example in Doherty power amplifier, the QWTL is served as impedance converter. Using a varactor based QWTL wideband performance can be achieved for the Doherty amplifier in a comparable way as what we did in this work. However, note that in an ideal Doherty power amplifier the characteristic impedance of impedance converter is constant. [25]. In our approach the impedance of tunable transmission line is changed with quarter wave frequency, so extra work is still required to avoid problems in the Doherty operation.

5.2.3. Differential Structure with Bondwire

Bondwires which directly connect to the die of the transistor can be used as circuit element and can provide better performance than those components at outside of transistor package. In this work the bondwires are used to implement a balun structure. Some interesting results are achieved in the end, which indicate the potential of this solution. This differential design is still in an initial stage so there might be other topologies and modifications that can be used to enhance the performance. The realization of the proposed topologies needs a detailed design study and more in depth simulations.

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