Novel Push–Pull Integrated Antenna Transmitter Front-End

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***Abstract*—A new integrated antenna power amplifier architecture is investigated. In this topology, a multifeed patch antenna is used as the tuned load of a class-B push–pull amplifier in such a manner that the fundamental radiates efficiently and higher harmonics are suppressed. This eliminates the necessity of using a second hybrid at the output of the amplifier and results in an extremely compact class of push–pull front end with lower associated circuit losses. Measured data shows that the power-added efficiency of the amplifier is greater than 55%, indicating that this new approach works as expected.**

***Index Terms*— FET, integrated antenna, power amplifier, push–pull.**

I. Introduction

ONE ONGOING research problem in the wireless area is the development of compact and low-cost transmitters for commercial applications. This is most readily realized with a compact and highly efficient front-end, which consumes the majority of the dc power in a transmitter. Minimal dc power consumption means smaller and longer lasting batteries, and smaller heat sinks, which typically takes up a large portion of the overall transmitter. Therefore, compact and highly efficient designs are vital for commercially viable transmitter front-ends.

Recently, the integrated antenna concept has been applied to meet these requirements [1]–[3]. In the active antenna approach, the power amplifier is directly integrated with the antenna and the antenna serves as a frequency-dependent load and radiator. This results in minimal matching, filters, and interconnects. Antenna characteristics become an integral part of the design process and have been demonstrated to be an effective method of performing harmonic tuning.

In this letter, we present a new and potentially broadband integrated antenna architecture which offers significantly higher output power. This architecture consists of a class-B push–pull power amplifier integrated with a multifeed planar antenna. The conventional push–pull amplifier offers twice the output power of its single-ended counterpart and excellent theoretical power-added efficiency (PAE) (78.5%) [4]. The integrated antenna architecture is significantly more compact than the traditional push–pull amplifier. Moreover, placing the active devices directly at the antenna minimizes output circuit losses and is the equivalent of using a 0-dB combiner.

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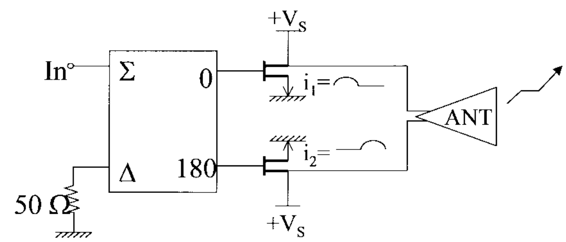

Fig. 1. Architecture of push–pull integrated antenna front-end.

II. New Push–Pull Architecture

The new architecture is based on using dual feeds to excite the proper mode profile in the antenna at the fundamental frequency and suppressing the radiation mode for higher harmonics. As shown in Fig. 1, the drain current at each device consists of a half sine wave with a phase shift of 180° between the two. Fourier analysis of the current waveforms shows that the two consist of a fundamental component that is antiphase, and a series of higher even harmonics that are in phase. Proper amplifier performance requires that the fundamental signals add in phase, and for higher harmonics to be reflected back to the amplifier with proper phase. A conventional MESFET push–pull PA uses a 180° hybrid to combine the output power. Our approach combines the two fundamental signals by feeding the antenna at two separate points in such a manner that the power in the fundamental combines. Additionally, the input impedance at these points can provide a reactive load at higher harmonics for harmonics termination. This eliminates the necessity of a second hybrid for a compact design with minimal circuit losses.

The antenna structure is of crucial importance for this new topology. In this study, a patch antenna is used with a microstrip feed placed at each radiating edge of the patch. The length of the patch antenna is approximately $\lambda/2$ at the design frequency. Inset feeds are used to obtain lower input impedance. Because the microstrip feeds are oriented in opposite directions, there is an inherent 180° phase reversal at the antenna structure. When combined with the push–pull topology, this means that the fundamental excitation of the antenna becomes *in-phase* and the higher harmonics become *antiphase*. Therefore, the power at the fundamental will add constructively for power combining.

III. Power Amplifier Design

This concept is used to design an integrated antenna push–pull amplifier. The amplifier is designed in HP Series IV design suite using MWT-8HP power field effect transistors.

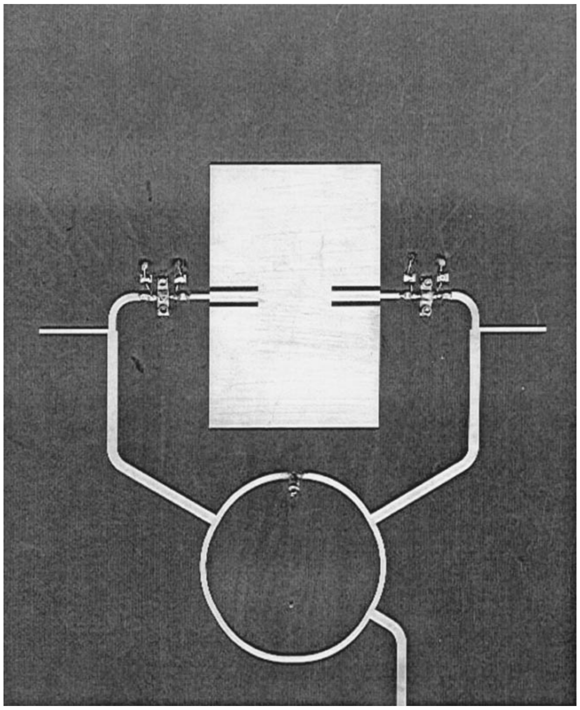

Fig. 2. Integrated antenna push–pull PA with dual-feed patch antenna.

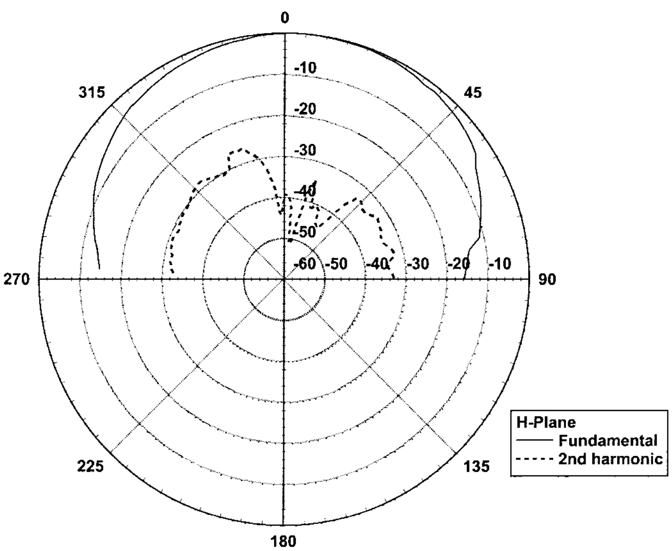

Fig. 3. Measured H-plane of push–pull front-end.

For accurate simulation, the patch is modeled as a two-port network, and measured S-parameters of the patch antenna are incorporated into the harmonic balance simulation. Because the patch does not provide perfect isolation, some power will flow between the two devices. Radiated output power is optimized for maximum performance at 2.5 GHz with 18-dBm input power. The structure is shown in Fig. 2. The hybrid and antenna occupy most of the structure. Elimination of the hybrid at the output has therefore significantly reduced circuit size, as well as reducing the output losses.

IV. Results

After fabrication, the patch is tested under design conditions for proper operation. First, E- and H-patterns, shown in Figs. 3 and 4, are measured for the first and second harmonics and calibrated using the Friis free-space equation. Higher harmonics were seen to have very small amounts of power and are not considered. From this we see that cancellation of the second harmonic is not perfect. Additionally, the patterns at the first and second harmonic closely resemble those of a single feed patch. The cross-polarization was also found to be comparable to that of a single-feed patch, better than 17 dB. Second harmonic suppression is estimated by integrating the total radiated power of the fundamental and second harmonic. From this, it is found that the total power in the second harmonic is 17 dB down from the fundamental. This amount of radiation at the second harmonic is reasonable for this structure, which radiates the (2, 0) mode and no specific efforts have been made to eliminate the second harmonic. This figure can be improved using the harmonic suppression techniques described in [1].

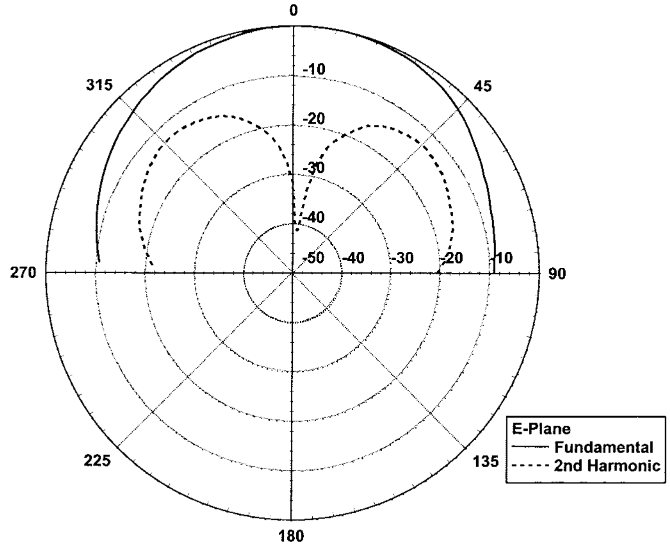

Fig. 4. Measured E-plane of push–pull front-end.

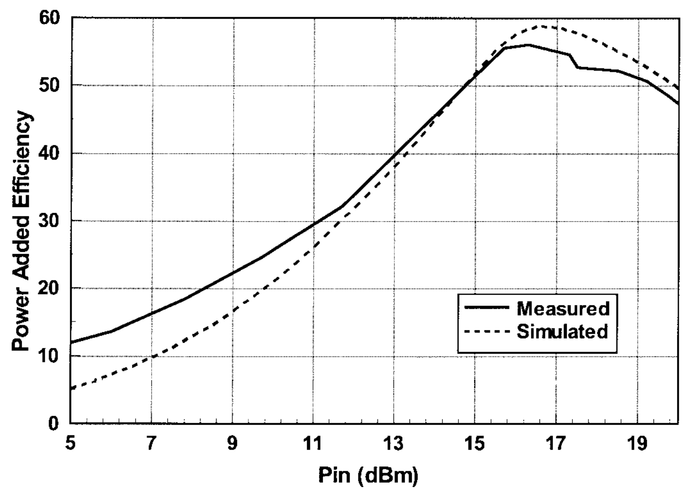

Fig. 5. Simulated and measure PAE for push–pull PA.

Knowledge of the amplifier PAE is essential and must be extracted through antenna measurements. This is done by "calibrating" the integrated antenna amplifier with a passive antenna structure. Simulated and measured PAE is shown in

Fig 5. Maximum PAE is approximately 55%. Good agreement indicates that the circuit is working as expected, and that the output power from the two devices is being combined effectively.

V. Conclusion

In this work, a new architecture for an integrated antenna push–pull amplifier has been presented. Power combining is accomplished through a novel feeding structure for the antenna. This structure eliminates the necessity of a second bulky hybrid at the output and its associated losses. PAE measurements indicate high efficiency operation of this novel push–pull PA. Current efforts are being directed toward reducing harmonic radiation levels to obtain a new generation of high efficiency and extremely compact transmitter front-ends.

References

[1] V. Radisic, S. T. Chew, Y. Qian, and T. Itoh, “High efficiency power amplifier integrated with antenna,” *IEEE Microwave Guided Wave Lett.*, vol. 7, pp. 39–41, Feb. 1997.

[2] V. Radisic, Y. Qian, and T. Itoh, “Class F power amplifier integrated with circular sector microstrip antenna,” in *IEEE MTT-S Int. Microwave Dig.*, Denver, CO, June 1997, pp. 687–690.

[3] ——, “Broadband power amplifier integrated with slot antenna and novel harmonic tuning structure,” in *IEEE MTT-S Int. Microwave Dig.*, Baltimore MD, June 1998, to be published.

[4] J. L. B. Walker, *High-Power GaAs FET Amplifiers.* Norwood, MA: Artech House, 1993.