A new true single supply power amplifier solution for dual and tri-band handsets

This paper describes the development and realisation of a three-stage dual-band single supply RF power amplifier for GSM900/DCS1800 cellular handsets. With output matching modifications, this device can be easily used in tri-band applications (GSM900/DCS1800/PCS1900). The IC is fabricated using 1µm pHEMT enhancement mode technology developed specifically for single supply solutions, and is assembled in a QFN32 package with exposed backside pad. This power pHEMT technology means that high power and high efficiency results are attainable for a low drain bias of 3.6V.

The need to develop cost-effective, easy to use, integrated solutions for dual-band solution transmitters presents a major challenge for semiconductor suppliers. The first generation of dual-band phones used single band PAs [1]. To reduce cost, both configurations have been merged on to a single chip [1,2]. Until now, power amplifiers for wireless applications have been produced almost exclusively in GaAs technologies with a few exceptions in LDMOS, Si BJT and SiGe HBT [3,5]. But conventional power pHEMT and MESFET's have a negative threshold voltage requiring a negative voltage generator (on chip or off chip) [1]. Therefore, to reduce cost and size, it was necessary to develop a normally off technology so that a negative voltage generator and drain switch would not be required.

The purpose of this paper is to report on the design and the characterisation of an integrated tri-band pHEMT power amplifier for mobile phone applications. First the design philosophy is presented with the pHEMT structure, active bias circuit and tuning methodology description. Then, GSM, DCS and PCS measurements are shown. Using this technology, power added efficiency of 55% @ 36dBm, 45% @ 35dBm and 40% @ 34dBm have been obtained in GSM, DCS and DCS/PCS bands respectively.

Figure 1: Tri-band simplified circuit diagram
control is carried out by changing the Vapc chip size and optimum performances. Power matching is done externally to maintain small input is matched to 50\Ohm

The GaAs pHEMT structure used in this study was grown by solid source molecular beam epitaxy. It consisted of an In GaAs channel with a Si\text{6} doping to obtain a high drain current density. This structure has been optimised to allow a positive threshold voltage. This technology, called E-mode, eliminates the need for a DC-DC converter [6] because the part requires only a single supply to operate at full capacity. For Vgs = 0V, the device is pinched off and the leakage current in OFF state is low enough to get rid of any drain switch [7]. This pHEMT can also be used in a variety of other RF and analogue applications requiring a single supply, high frequency, low noise transistor with large transconductance.

Our RFIC is composed of pHEMT E-mode transistors, via holes, spiral inductors, MIM capacitors and resistance using the implanted layer. A simplified circuit diagram of the power amplifier is shown in Figure 1. The input is matched to 50\Ohm

In dual-band configuration, output matching is performed in both bands with two-stage low-pass networks and is easily implemented with shunt capacitors mounted along a 50\Ohm microstrip transmission line. Value and position are chosen to reach the load line impedance of 2\Ohm while conjugating the device output parasitic. The network must also properly terminate second and third harmonic levels in order to get the best output power and efficiency performances. The choice of the output matching capacitor type and supplier will affect the series resonant frequency and hence H\text{2}, H\text{3} levels and efficiency.

Under matching conditions, the device is easily tuned to cover 200MHz bandwidth (1710MHz to 1910MHz) with less than 1dB gain ripple versus frequency. To increase the band pass of the power amplifier, one has generally to reduce the parasitic in the application by using high Q lumped components. In comparison with dual band application, tuned an appropriate tri-band application has been by replacing several critical components by some of higher Q.

**Results and discussion**

Measurements were performed on a standard FR4 PCB to agree with the production environment an external output matching adjusted for optimum output power and power added efficiency compromise. This amplifier is designed to meet the European Telecommunications Standards Institute (ETSI) GSM document, which is defined as follows: t\text{on} = 570\mu s, T = 4.16ms and duty cycle of 12.5\%. Multislot operation can also be implemented up to 4Tx without significant power performance degradations.

Figure 4 represents the output power and the power added efficiency versus frequency for different supply voltage in the GSM band @ P\text{in} = -1dBm. P\text{out} is flat within 1dB ripple across the band. The maximum PAE is higher than 57\% for a P\text{in} equal to 36dBm @ 3.6V. The PAE max remains better than 55\% for a maximum P\text{out} of 34dBm @ 2.8V. To our knowledge these are the best results.
found for integrated tri-band power amplifier [1-12]. The high value of the small signal gain, due to the pre-amplifier, is around 44dB. The second and third harmonic outputs are typically around -50dBc with a second harmonic leakage at DCS output (crosstalk isolation) of -20dBm. The output power isolation is 38dBm at Pin = 0dBm and Vapc = 0 V. Finally, no electrical degradation has been observed after the load mismatch stress test for a 10:1 VSWR in the output power range.

The following results are obtained in the 1710 - 1785MHz DCS band for 2dBm input power. Over 35dBm output power and 45% power added efficiency have been obtained in this band for a 3.6V supply voltage as shown in Figure 5. The same measurements at 2.8V have shown an output power of 34dBm with an associated 44% PAE. These performance figures for Pout/PAE compare favourably with previous results [1,2,4,12]. The second and third harmonic outputs are typically around -43dBc and -65dBc respectively with an output power isolation of -39dBm at Pin = 5dBm and Vapc = 0 V.

Conclusion

A true single supply tri-band power amplifier MMIC for GSM and DCS1800/PCS1900 handset applications has been developed, using novel enhancement mode technology. Outstanding level of performance is reached on RF side with typical values of 57% @ 36dBm, 45% @ 35dBm and 42% @ 34dBm respectively for GSM, DCS and DCS/PCS. This device is simple to use, does not need a negative voltage generator or drain switch, and allows a low cost and surface for complete application. The Enhancement mode technology used appears to be a suitable process for European and American cellular bands.

Acknowledgments

The Authors would like to thank J. Mercader and J. L. Vayr for their contribution.

References

amplifier with 59% PAE at 0.9 GHz”

Figure 6a: DCS/PCS output power versus frequency as a function of drain voltage.

Figure 6b: DCS/PCS power added efficiency versus frequency as a function of drain voltage.