ACPR Comparison of Low Pass and Band Pass Type Power Amplifier for 22Mbps Wireless LAN Application

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Abstract

This paper reports the ACPR effects of matching network topology. To investigate the out-of-band termination effects, a low pass filter (LPF) and a band pass filter (BPF) type power amplifiers are designed. The LPF type shows a maximum 5dB ACPR improvement on the BPF type. ACPR degradation by phase non-linearity is also predicted with simple AM-to-PM modeling

Introduction

Most modern wireless communication systems make use of digital modulation, and the data rate becomes higher as the transmission of multimedia information increases. Adjacent channel power ratio (ACPR) is the linearity figure of merit for the power amplifier employed in digital wireless systems.

Some papers of ACPR analysis can be found for the cellular or PCS amplifier[1-3], but as yet few research papers have been published for the 2.4GHz wireless LAN which has a high 22Mbps data rate. As the occupied bandwidth gets wider and PSK and QAM become popular modulation schemes, more consideration is required for the phase distortion of the power amplifier[4]. And there have been some investigations about the effect of out-of-band terminations on inter-modulation distortion, which causes ACPR degradation[5-8].

This paper reports a power amplifier design with analytic and numerical consideration of ACPR for the 22Mbps spreaded wireless LAN application. In the implementation, for investigating the effect of out-of-band terminations in a practical way, a low pass filter (LPF) and a band pass filter (BPF) type amplifiers are designed and compared for the ACPR performance. And for simulating the effect of the phase non-linearity on the amplifier back-off (i.e. the difference between 1dB compression output and the maximum output which meets the ACPR specifications), a simple AM-to-PM numerical model has been proposed which gives how much phase distortion can be tolerable for the specified ACPR.

The designed amplifier has been realized as a compact HMIC for a PCMCIA wireless LAN card, and measured results are presented and compared with the simulated performance.

Modeling and Design

To show the out-of-band termination effects on the third-order intermodulation (IMD3) and the fifth-order intermodulation (IMD5), some performance comparisons have been done for the LPF and BPF type amplifiers. That is a practical way to realize different out-of-band terminations.

The ACPR simulation has been done in two ways. MATLAB is used for the modeling of signals, amplitude and phase nonlinearity. This gives insight into the nonlinearity effects on the ACPR performance.

Also, we have simulated a wireless LAN system, with modeling direct sequence spread spectrum (DSSS) modulation and RF subsystem, considering some practical parameters with envelope simulation technique. In the simulation, 22Mbps modulated 2.4GHz signal source is modeled with reference to the IEEE 802.11 standards.

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In Figure 1, the required transmit spectrum mask for the standard wireless LAN system is presented[9].

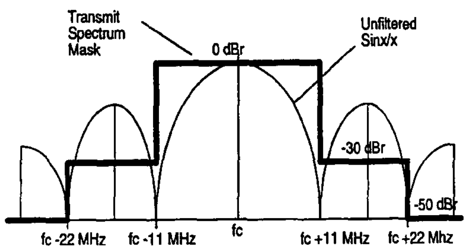

Figure. 1 Wireless LAN transmit spectrum mask[9].

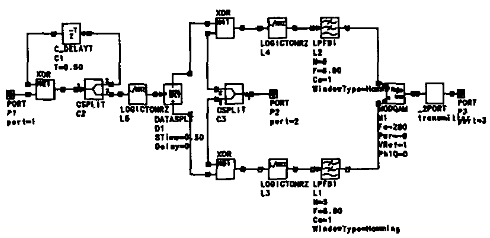

Figure.2 Modeling of baseband, modulator and transmitter for the wireless LAN system.

The wideband signal source consists of baseband, modulator and RF transmitter. The baseband processor spreads the signal after input is encoded as differential data. And the RF section consists of modulation part, frequency up-converter, a drive amplifier and a power amplifier. Figure 2 is the circuit schematic of baseband processor, modulator and transmitter.

Two types of 3-stage GaAs MESFET amplifiers have been designed with the specifications in Table 1.

Table 1. Design specifications and measured data of a three stage amplifier

PARAMETER	SPEC.	MEASURED	UNIT
Frequency	2.4	2.4	GHz
Linear Gain	28	28.5	dB
Output Power at P_1dB	+25.5	+25.7	dBm
Efficiency	30%	32%	%
Input Return Loss	-11.3	-19.1	dB
Output Return Loss	-11.3	-12.0	dB
2 nd Order at P_1dB	-20	-41.3	dBc
3 rd Order at P_1dB	-30	-35.3	dBc
ACPR at | f-fc | >11MHz	-30	-31.0 Pin=-4.5dBm	dBr
ACPR at | f-fc | >22MHz	-50	-51.8 Pin=-4.5dBm	dBr

We have designed the first and second stages by using S parameters, and final stage with a nonlinear GaAs MESFET model. Trap capacitances are used in a bias circuit to realize a small and efficient amplifier for the PCMCIA application[10].

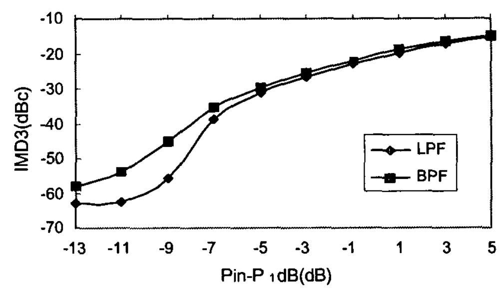

Figure 3. IMD3 characteristics for LPF and BPF type power amplifiers.

ACPR Simulation and Experiment

For the ACPR simulation with the 2.4GHz DSSS source, the power amplifier is modeled with large-signal S parameters. The simulation shows that the LPF type amplifier has better ACPR performance than the BPF type amplifier. This is what we have expected from the IMD3 analysis shown in Figure 3. As shown in Figure 4, the LPF amplifier has a 3.5dB improvement in IMD3 related ACPR (i.e. ACPR from 11MHz to 22MHz offset from center frequency). Also for the IMD5 related ACPR (i.e. more than 22MHz apart from center frequency), the LPF type has 5dB better performance around 50dBr specification.

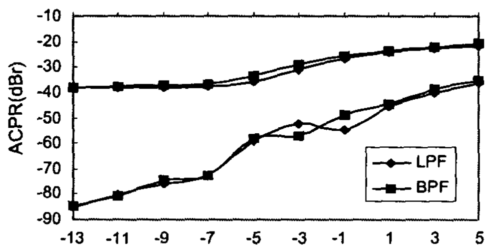

Figure 4. ACPR characteristics of LPF and BPF type power amplifiers (upper: 11MHz ~ 22MHz, lower: >22MHz apart from center fequency)

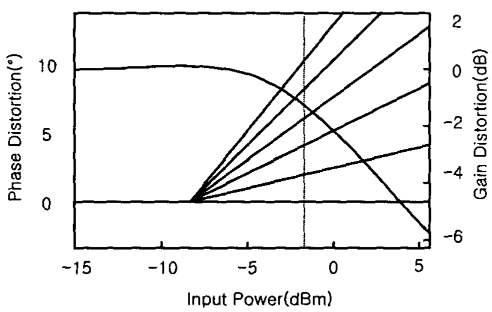

Figure 5. Simulated gain and phase distortion (for a fixed gain, linear phase distortion which ranges 0° to 10° at P_1dB is modeled).

For the investigation of AM-to-PM effects on the backoff, the amplifier has been modeled with AM-to-AM and AM-to-PM characteristics.

A simple numerical phase distortion model is developed as in Figure 5. This model is useful for relatively small AM-to-PM, and can be used to show the backoff degradation caused by phase distortion.

For the designed amplifier, it was shown that an additional 0.6dB backoff degradation is coming from phase distortion. If the amplifier has 10° AM-to-PM at the 1dB compression point, the simulation shows that an additional 2.5dB backoff is required to satisfy the ACPR characteristics. The measured phase nonlinearity shows 2.5° at P_1dB, and is in good agreement with the model.

We have measured gain, power and ACPR characteristic for the LPF and BPF type amplifiers with microwave instruments and 22Mbps modulated 2.4GHz wireless LAN signal generators.

The measured result of the LPF type 3-stage amplifier is shown in Table 1. The measured ACPR with the input power of –4.3dBm (i.e. 2.5dB lower than 1dB compression input) is less than -30dBr and -50dBr beyond 11MHz and 22MHz from center frequency, which meets the wireless LAN standards. Compared with the BPF type, this shows 0.9dB improvement in the input power level which meets the specification.

When the -30dBr specification is satisfied over 11MHz to 22MHz from center, the -50dBr specification beyond 22MHz is always satisfied for the simulation and measurement. The measured and simulated ACPR with more than 11MHz offset from carrier center is shown in Figure 6. The measured ACPR shows close agreement with the simulation data.

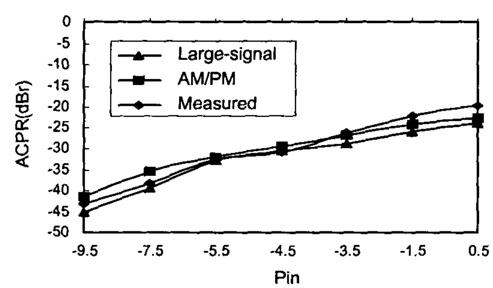

Figure 6. Measured and simulated IMD3 related ACPR with input power(LPF type amplifier).

The measured ACPR and the simulated data by large-signal S parameters shows less than 1dB difference up to –4.3dBm input (i.e. the maximum input to meet the ACPR specification). In this power range, the large signal S parameters from GaAs MESFET modeling are sufficiently accurate.

With high input power up to 0dBm, the difference increases up to 2.5dB (however, notice that the measured ACPR value increases by 25dB from –45dBr to –20dBr). For such power level, the simulation accuracy is better when using the AM-to-AM and AM-to-PM values measured over 20dB power range for the amplifier modeling.

Conclusions

The design strategy for power amplifier topology is presented for a 22Mbps wireless LAN system. The different out-of-bandwidth termination is realized as a LPF or BPF type matching network, and the LPF type can deliver 0.9dB more power than the BPF type with the same ACPR.

And with the same input, the LPF type has a maximum 5dB ACPR improvement. The effect of phase distortion is analysed, and for this wide-band application, it is shown that several decibels of back-off degradation may be caused by the AM-to-PM non-linearity.

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References

[1] S.Chen, W.Panton and R.Gilmore, "Effects of Nonlinear Distortion on CDMA Communication Systems," *IEEE MTT-S Int. Microwave Symp.* Dig., pp.775-778, 1996.

[2] J.Sevic and J.Staudinger, "Simulation of Power Amplifier Adjacent Channel Power Ratio for Digital Wireless Communication Systems," *IEEE MTT-S Int. Microwave Symp.* Dig., pp.681-684,1996.

[3] H.Gutierrez, K.Grad and M.Steer, "Spectral Regrowth in Microwave Amplifier Using Transformation of Signal Statistics," *IEEE MTT-S Int. Microwave Symp.* Dig., pp.985-998, 1999.

[4] S.Cripps, *RF Power Amplifiers for Wireless Communications*, Artech House, 1999.

[5] S.Mass, *Nonlinear Microwave Circuitss*, Artech House, 1998

[6] R.A.Minasian, "Intermodulation Distortion Analysis of MESFET Amplifier Using Volterra Series Representation ," *IEEE Trans. Microwave Theory Tech.*, vol.28, pp.1-8, Jan.1980.

[7] J.Sevic, K.Burger and M.Steer, "A Novel Envelope Termination Load–Pull Method for ACPR Optimization of RF/Microwave Power Amplifiers," *IEEE MTT-S Int. Microwave Symp. Dig.*, pp.723-726, 1998.

[8] V.Aparin and C. Persico, "Effect of Out-of-Band Terminations on Intermodulation Distortion in Common Emitter Circuits," *IEEE MTT-S Int. Microwave Symp.* Dig., pp.977-980, 1999.

[9] *Wireless Lan Medium Acces Control (MAC) and Physical Layer (PHY) Specifications*, IEEE Computer Society, July 1996.

[10] M.Nishida, S.Murai, H.Uda, H.Tominiga, T.Sawai and A. Ibaraki, "A High Efficiency GaAs Power Amplifier Module with a Single Voltage for Digital Cellular Phone Sysyems," *IEEE MTT-S Int. Microwave Symp.* Dig., pp.743-746, 1997.