IEEE 802.11
Wireless Access Method and Physical Layer Specifications

2.4 GHz GaAs MMIC Experimental Results of FQPSK and DQPSK

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Abstract

Using Teledyne's recently released TFE-1050 GaAs MMIC transceiver and TAE-1010A amplifier, and a 1 Mb/s digital baseband FQPSK-1 processor, the power spectra of FQPSK-1 under various degrees of filtering and amplification were experimentally obtained at the 2.4 GHz band. This data was then compared with 1 Mb/s DQPSK under like conditions. From these results, we conclude that FQPSK-1 has at least a 66-100 % power advantage at room temperature over DQPSK at room temperature. The RF power improvement could be even larger if temperature variations and AM/PM conversions are taken into account. In addition, indications are that for a 3V battery, FQPSK-1 is more than twice as efficient as DQPSK. The combined hardware impact of the increased (double) power transmission and higher power efficiency (beneficial to battery life time) with FQPSK-1 could be an essential consideration for efficient design.

Introduction

For wireless applications, the choice of modulation is very important as it affects the spectrum of a transmitted signal. By FCC regulations, wireless products must have power spectral densities that fit within pre-defined spectral masks. Further, out of band components should be minimized in order to avoid system degradations due to adjacent channel interference. Ideally, a transmission should have the same spectral shape independent of the power level of the transmitter; unfortunately, saturation of an amplifier will, in general, cause spectral regrowth of variable envelope modulation schemes.

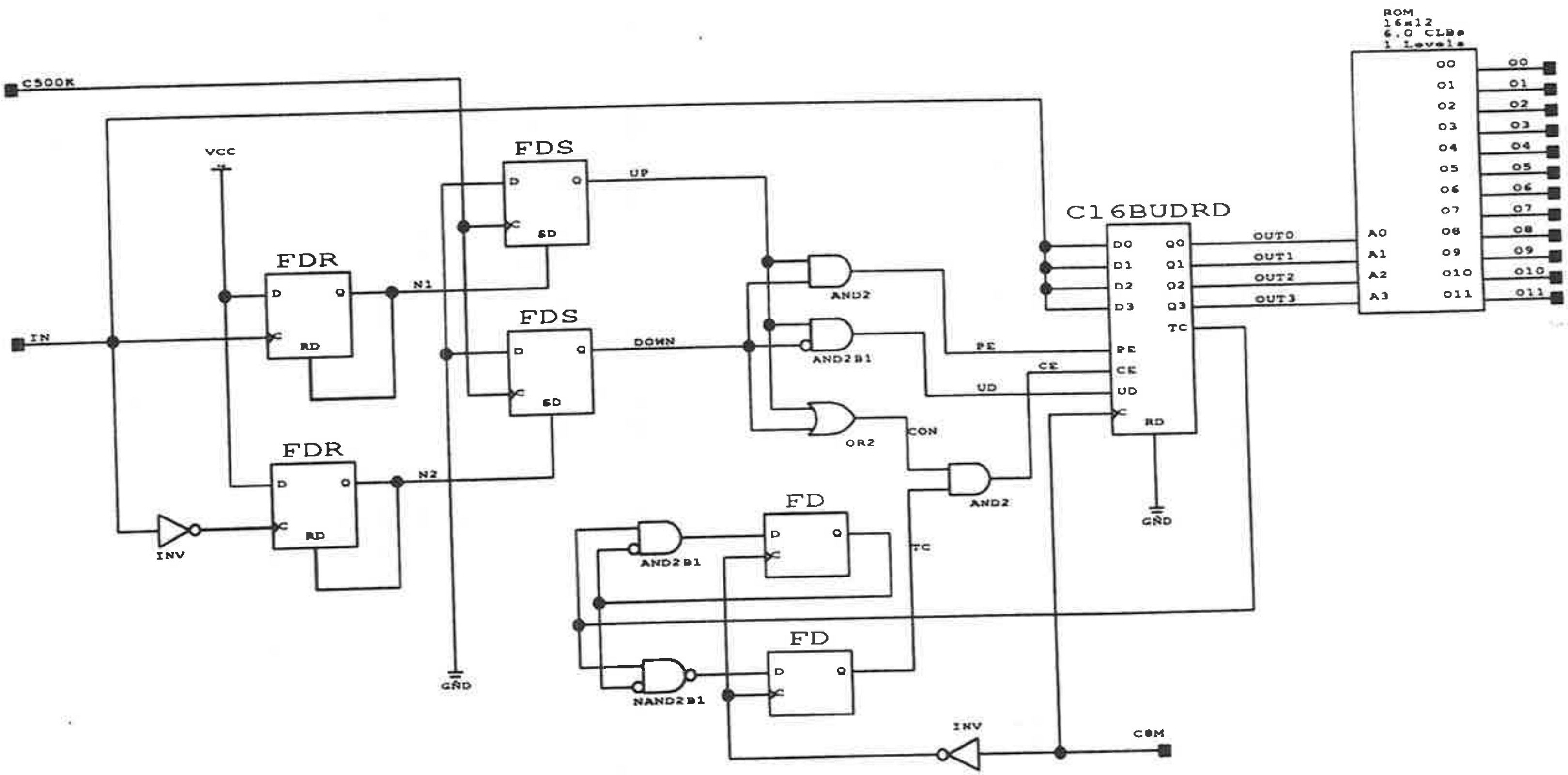

Figure 1
FPGA Implementation of FQPSK
Baseband Modulator

R. Atienza
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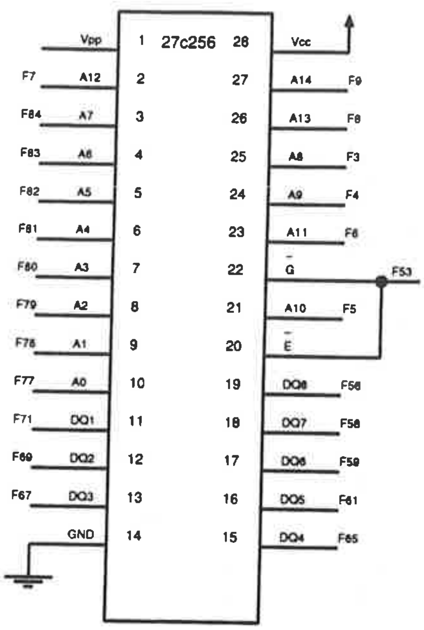
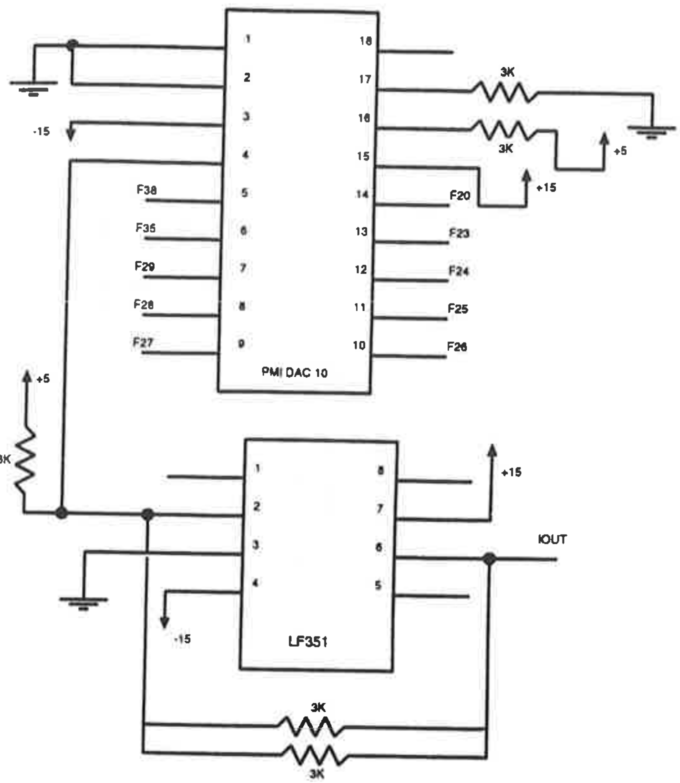
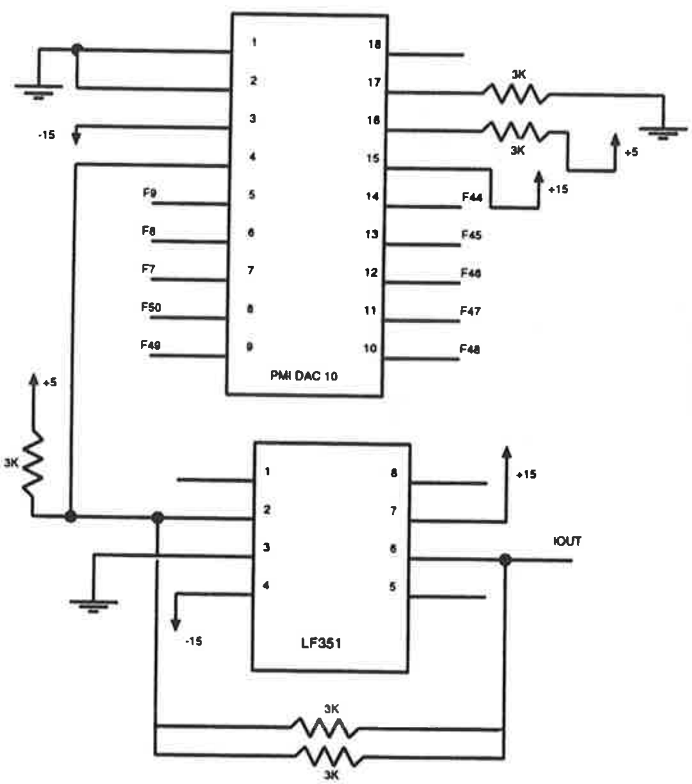
ijfai2
Xilinx-IJF DAC
Interface



Eprom connection to FPGA



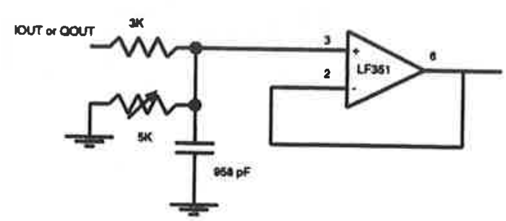
I-Channel DAC interface



Q-Channel DAC interface

F51: Clock In
F66: Clock Out
F57: Data In

Other FPGA Connections



Smoothing filter connection to outputs I Out / Q Out

Figure 1
FPGA Implementation of FQPSK
Baseband Modulator

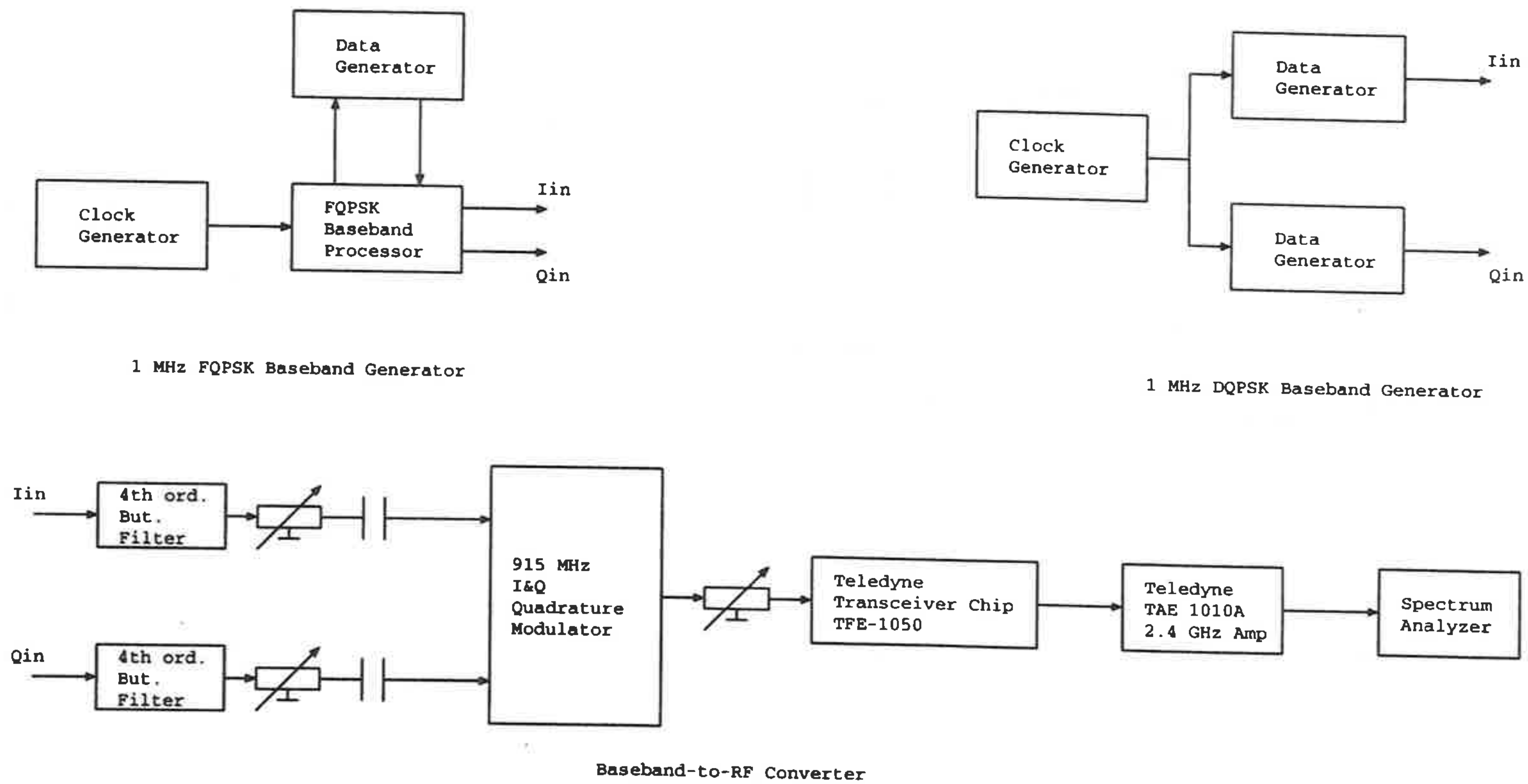
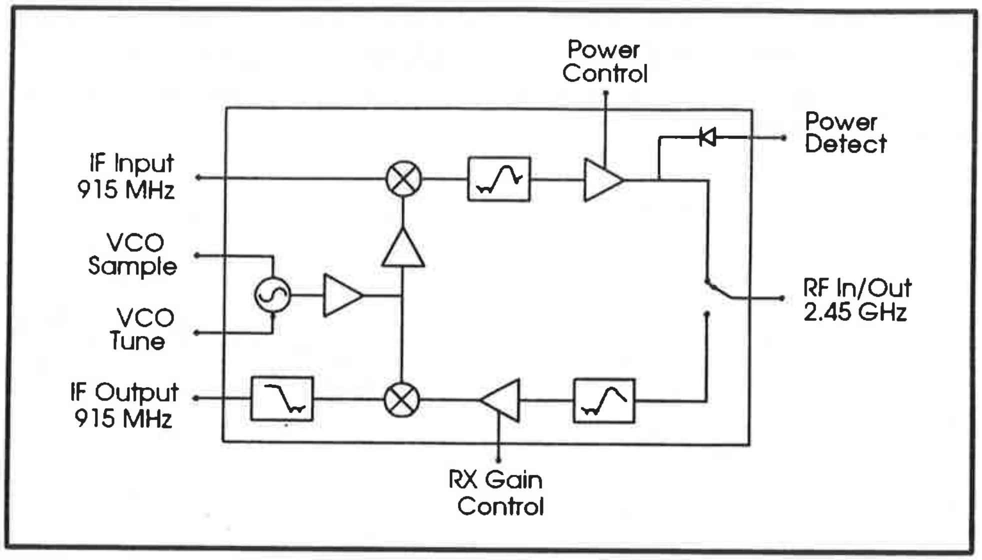


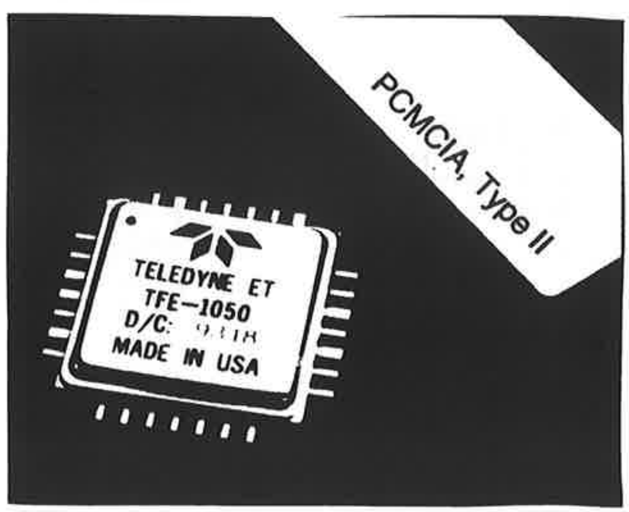
Figure 2: Experimenal Setup

Product Description:

The model TFE-1050 transceiver provides a packaged single-chip solution for translating 915 MHz products to the US/International 2.4 GHz ISM band. The upconvert path provides 30 dB conversion gain with 24 dBm linear output power. The downconvert path contains a low noise amplifier with switchable gain states and consumes less than 250 mW in the receive mode. Other features include output T/R switching at the 2.4 GHz interface, power management control, and on-board VCO suitable for PLL operation.

Functional Block Diagram:





Experimental Measurements

These experiments were performed according to the setup as shown in Figure 2. Using the above modulator, a 1 Mb/s FQPSK-1 signal was generated and quadrature modulated to 915 MHz. The resulting signal was then upconverted to 2.4 GHz using Teledyne's TFE-1050 GaAs MMIC transceiver, and amplified using a TAE-1010A power amplifier. An attenuator was placed after then quadrature modulator to ensure linear operation of the transceiver. For comparison, a 1 Mb/s DQPSK signal was also generated, using two synchronized PRBS generators. Figures 3a through 3d depict the power spectral densities of unfiltered FQPSK-1 and DQPSK signals under linear and non-linear amplification. As can be seen here, 1 Mb/s FQPSK-1 can comfortably meet the requirement of 20 dB attenuation in a 1 MHz bandwidth, as would be required in the spectral specifications of the IEEE 802.11 FH-SS PHY.

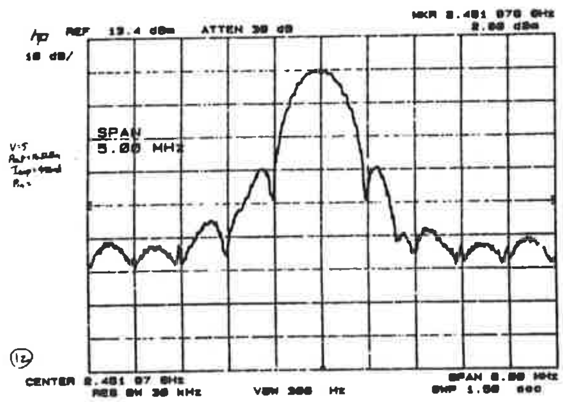


Figure 3a: Linearly Amplified FQPSK

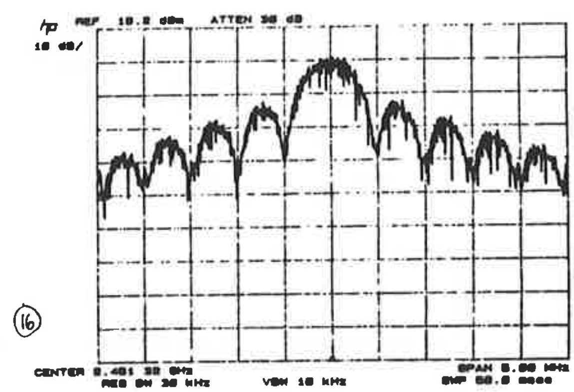


Figure 3b: Linearly Amplified DQPSK

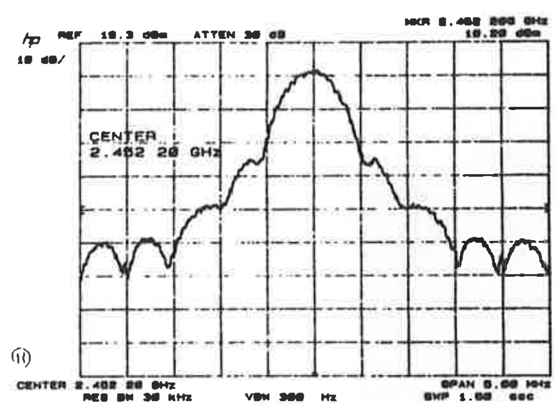


Figure 3c: Nonlinearly amplified FQPSK

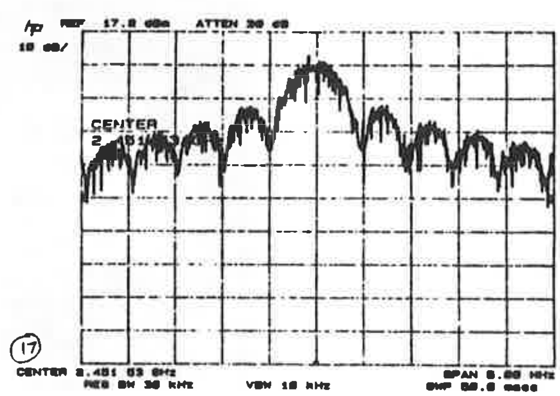


Figure 3d: Nonlinearly amplified DQPSK

To simulate the PSD of FQPSK-1 and DQPSK modulated signals under IEEE 802.11 DS-SS specifications, a chipping frequency of f_c = 500 kHz was assumed, scaled down from the actual 11 MHz frequency specified in [6] by a factor of 22. Thus, it was desired to force each spectra below -30 dBc at Δf = 500 kHz and below -50 dBc at Δf = 1 MHz. For FQPSK-1, a cutoff frequency of 1MHz was required, while for DQPSK somewhat narrower bandwidth filters with a cutoff frequency of 300 kHz were necessary. In Figures 4a and 4b, the PSD of these signals after linear amplification are shown.

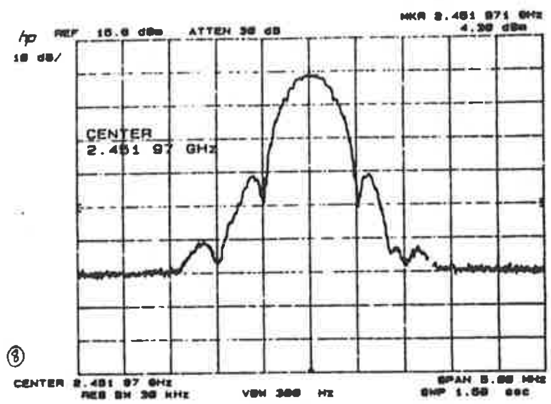


Figure 4a: Linearly amplified filtered FQPSK-1
Output: 17.7 dBm
Power Supply: 3V

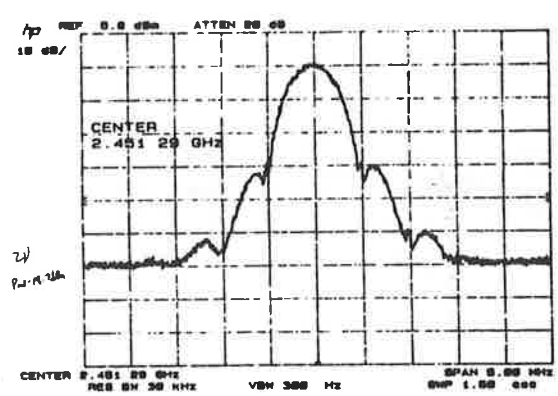


Figure 4b: Linearly amplified filtered DQPSK
Output: 18.3 dBm
Power Supply: 3V

In general, if a filtered QPSK signal is fed to an amplifier operating in a near-saturated or saturated mode, spectral sidelobes will regenerate, undoing any spectral shaping as a result of baseband filtering. Figures 5a and 5b illustrate this phenomenon for filtered FQPSK-1 and DQPSK signals, with the amplifier operating at an 11dB compression point. The amount of spectral regrowth is significantly greater in the DQPSK case.

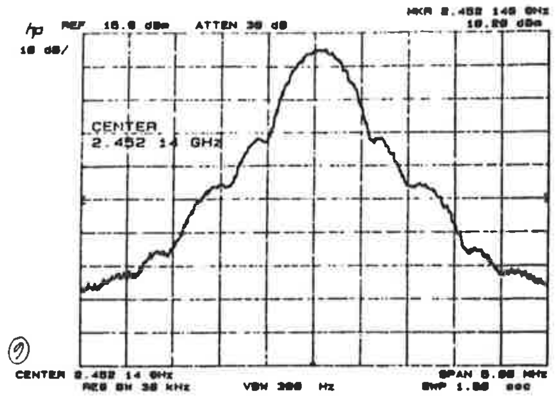


Figure 5a: Saturated filtered FQPSK-1
Output: 24.0 dBm
Power Supply: 3V

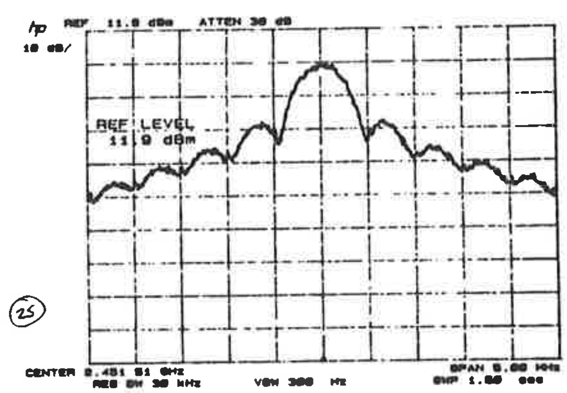


Figure 5b: Saturated filtered DQPSK
Output: 24.0 dBm
Power Supply: 3V

Neither FQPSK-1 nor the filtered DQPSK can meet the requirements of the DS-SS or Higher Speed FH PHY under saturation conditions. However, it is interesting to note that while FQPSK-1 has a minimum of 27 dB attenuation at $\Delta f = f_c$, the attenuation of filtered DQPSK is only 17dB. In order for our filtered DQPSK to match the level of attenuation of FQPSK-1, the amplifier needed to be backed off by 2 to 3 dB (Figure 6). As a result, amplifier efficiency is greatly reduced (Figure 7). Since the transmit amplifier is a major source of power consumption, FQPSK-1 hardware can potentially provide a more power efficient system.

	3V Power Supply	5V Power Supply
Saturated FQPSK-1	24.0 dBm	28.5 dBm
Filtered DQPSK	21.1 dBm	26.5 dBm

Figure 6: Amplifier power level for 27 dB attenuation at $\Delta f = f_c$
Measured at Teledyne Electronic Technologies, Mountain View, CA

	3V Power Supply	5V Power Supply
Saturated FQPSK-1	19.8 %	28.8 %
Filtered DQPSK	8.6 %	16.5 %

Figure 7: Amplifier efficiency for 27 dB attenuation at $\Delta f = f_c$
Measured at Teledyne Electronic Technologies, Mountain View, CA

Variations of FQPSK e.g. FQPSK(kf) can meet the required specifications for the DS-SS and High-Speed FH PHYs [8].

Conclusion

For wireless LAN applications, horror stories of the low efficiency of power amplifiers do not necessarily preclude the use of orthogonal modulation techniques. High power, higher efficiency transmission can be realized through the use of FQPSK-1 hardware.

References

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