DESIGN CONSIDERATIONS FOR DEVELOPMENT OF AN AIRBORNE FQPSK TRANSMITTER

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ABSTRACT

This paper describes the design considerations used by Aydin Telemetry in the development of its high data rate Feher Patented Quadrature Phase Shift Keying (FQPSK) [1] frequency agile transmitter. We will address several key areas of interest to the Telemetry community, such as the use of commercially available VLSI parts to minimize parts count while maximizing reliability, adaptive filtering to accommodate a wide range of data rates, and user selectable features to achieve a universal transmitter design. User selectable features include differential encoder, 15 stage IRIG randomizer, and 1/2 rate convolutional FEC coding. This paper also addresses the spectral efficiency that can be achieved using a Class-C amplifier with FQPSK and the measured bit error rate (BER) performance versus Eb/No.

KEY WORDS

Modulation, Feher's Patented Quadrature Phase Shift Keying, bit error rate, non linear amplifier

INTRODUCTION

With the decrease of available spectrum as well as the requirements for increased data rates, a more spectral efficient modulation technique must be employed. Aydin Telemetry, along with many other government and commercial organizations have employed FQPSK [1] in their developments due to the ability to operate under the use of non linear amplification (NLA) to maintain good DC efficiency without compromising BER performance. Today industry development funds must be managed to yield the most agile product possible so one product can meet most user needs without the need for modification. Customer needs range from High DC efficiency, Bit rate agility, and RF power output from 2 to 10 watts.

DESIGN CONSIDERATIONS

When developing a new product, one needs to consider the many variations, which may be required by potential customers. During this phase of the development, areas we considered are DC efficiency, Frequency and bit rate agility, as well as, RF output power. The first area we considered is DC efficiency.

Secondly, we considered the products agility. Due to the use of direct modulation and a frequency agile LO, it's possible to meet any required frequency in S Band (2200 - 2400MHz) or L Band (1435 - 1534MHz) with minimal component changes. The use of a selectable low pass filter allows us to meet any desired bit rate from 2 to 20Mb/s without component changes. To improve on this concept, the incoming bit clock will be internally counted for proper setup of the agile filter and transfer this information to the filter via the FPGA. The introduction of the agile filter had no adverse affect on the spectrum or BER performance.

Lastly, the size and outline of the transmitter must be minimized to fit existing configurations. Aydin's T400 outline was chosen for this design due to the industry standard footprint associated with it. To meet this size and shape, a minimized parts count must be employed. The use of packaged modem components has proved useful. Utilizing a single chip clock multiplier to generate the reconstruction clock, dual DAC's for wave reconstruction, FPGA for the associated digital circuitry, as well as an ASIC dual bit rate agile filter. This footprint could not be realized without the use of these commercially available modem components.

KEY AREAS

Automatic Bit rate detection

The incoming data clock is fed into a FPGA implemented counter (see fig 1). After the completion of the 100ms-gate time, the result will be used to create the address where the filter configuration table is stored. These configurations are sent to the filter via 3 line serial bus. Within 100ms after the configuration has been sent the filter the configuration will be complete. Due to the low resolution of the Bit rate counter small variations due to clock jitter will have no affect on the filter configuration.

FPGA implementation

The block diagram shown in figure 2 shows the FQPSK implementation for the modulator and FEC. Incoming data is clocked through the serial/parallel converter to create I/Q data paths, activation of the FEC would occur prior to the S/P. The cross correlator adds a controlled amount of correlation between the I and Q channels. This means that the output level of the I channel [or Q channel] is dependent on the present and previous input symbol level of the I channel as well as the Q channel. Therefore the output level of the I channel is dependent upon four symbol states. (two for I and two for Q). the result, is the ability to create a constant envelope (zero envelope fluctuation). A constant envelope must be maintained to ensure minimal spectral re-growth under Class C amplification (NLA). The DAC used is simple dual I/Q, single supply type typically used modem applications. The DAC was found to be of low cost and size, yet maintain sufficient accuracy and low power consumption.

OPTIONS

Several user selectable options are included in our design. The operating frequency will be user selectable via TTL interface. Forward Error Correction will be user selectable for ½, ¾ and 7/8 convolutional encoder to aid in burst errors. Enabling of the IRIG 15-stage randomizer will allow lower data rates to be used. A differential encoder has been added to resolve the phase ambiguity. The differential encoder will force proper phase alignment when demodulating.

FUNCTIONAL BLOCK DIAGRAM

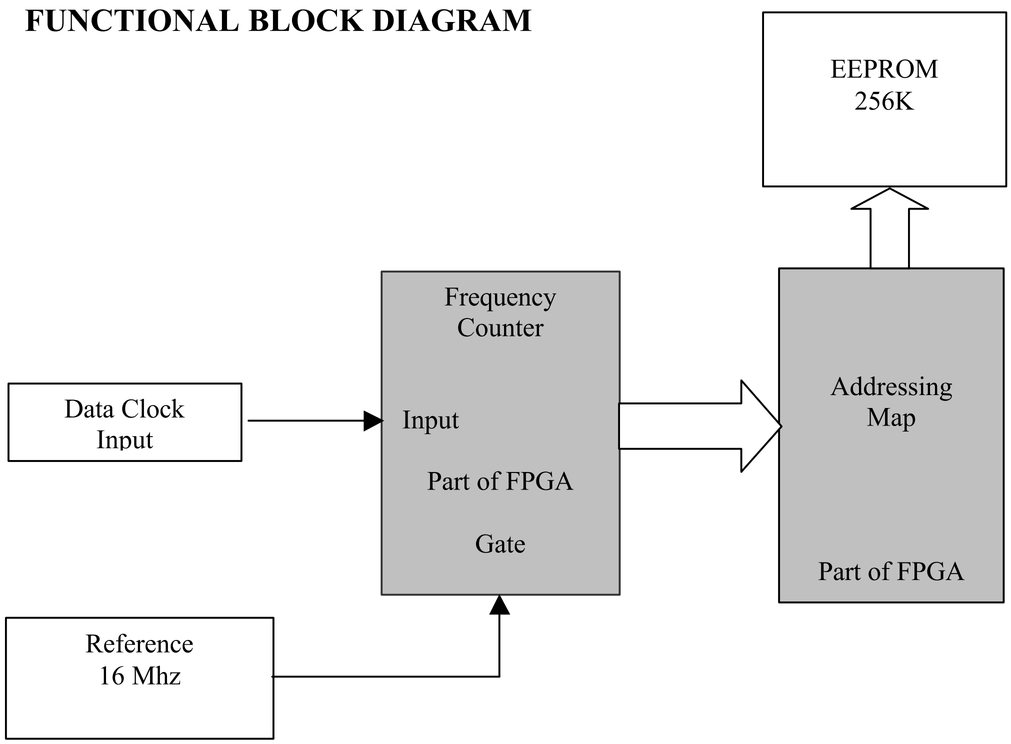


Figure 1. Automatic filter configuration circuit.

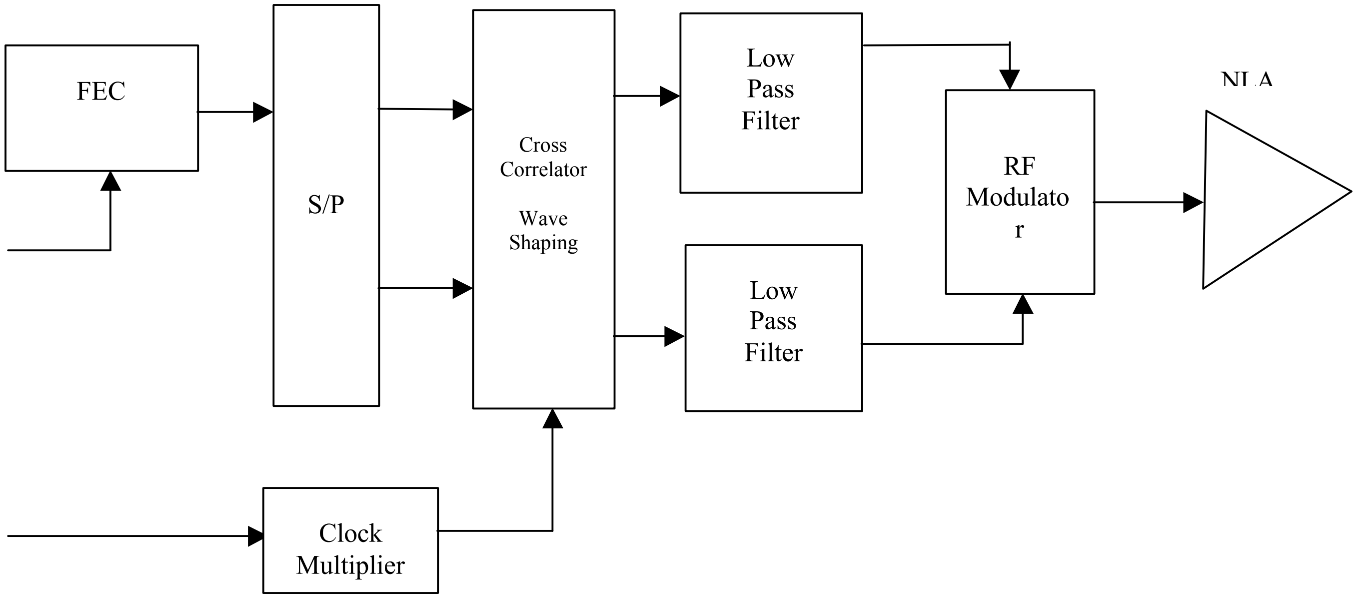


Figure 2 Block diagram of FQPSK transmitter having a baseband processor and RF modulator

LABORATORY TEST DATA

The transmitter was tested for carrier suppression, spectrial purity, and BER performance under the configuration of figure 3. In this lab, the carrier suppresion was set to a minimum of -35 dbc and verified over the operating temperature span of –20 to 70 deg C.

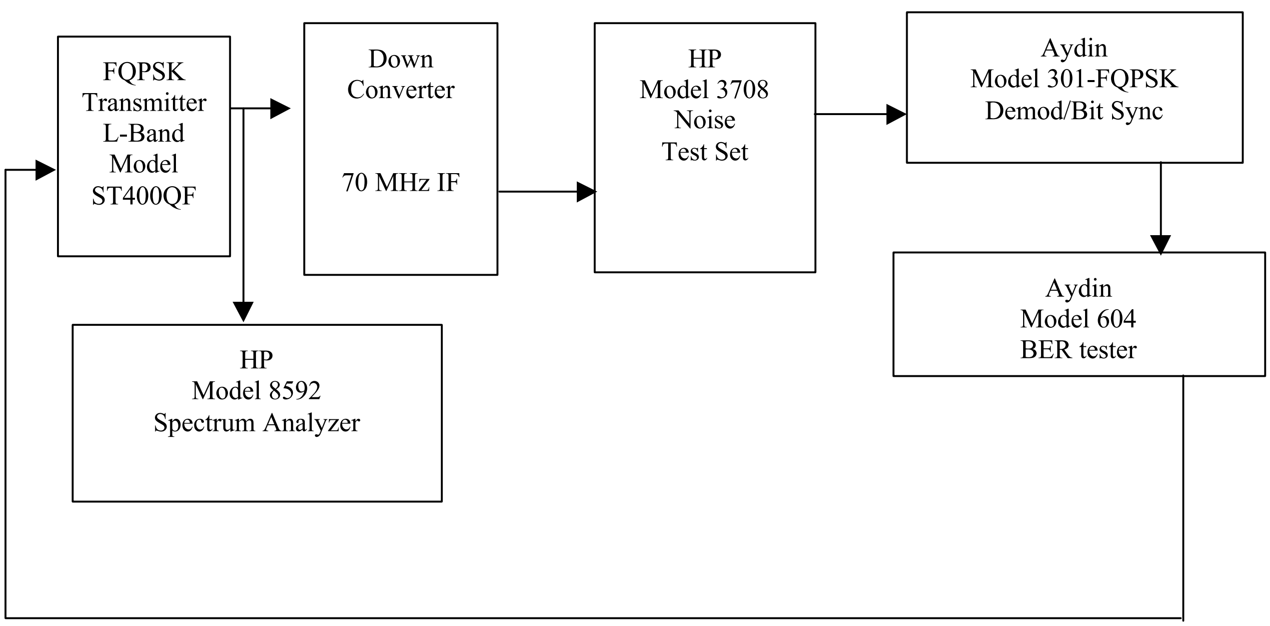


Figure 3 Spectrum and BER performance test set

The transmitter spectrum of class C amplified FQPSK was verified and compared to that of Ref [3] and other ITC papers. The BER results of Figure 3 are 5 mb/s and Figure 6 ½ convolutional FEC 2.5 mb/s. All FQPSK receiver testing was conducted using Aydin's model 301 demodulator and bit syncronizer in staggered QPSK mode.

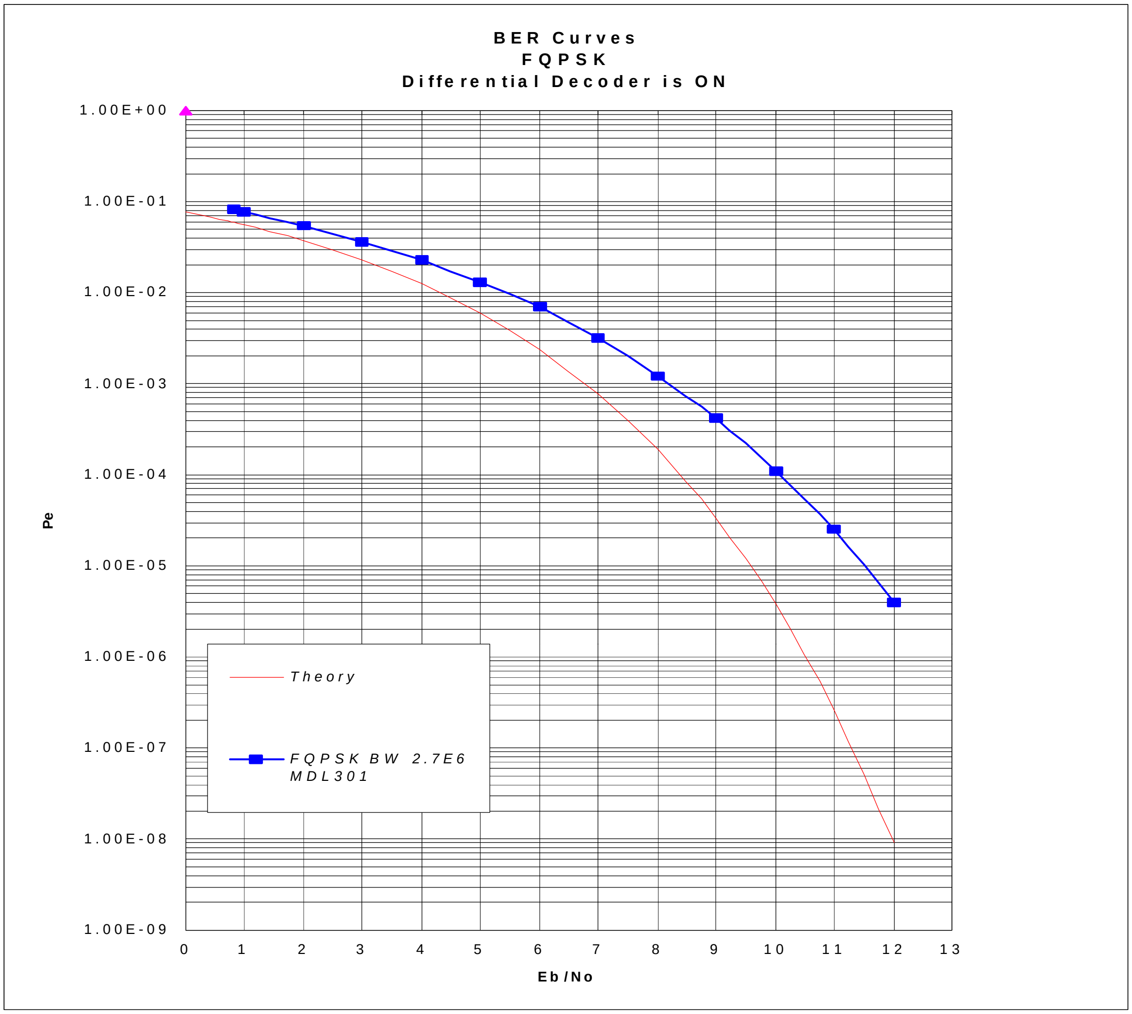


Figure 4 Measured BER performance of a direct modulated L band FQPSK non-linearly amplified transceiver in an AWGN channel.

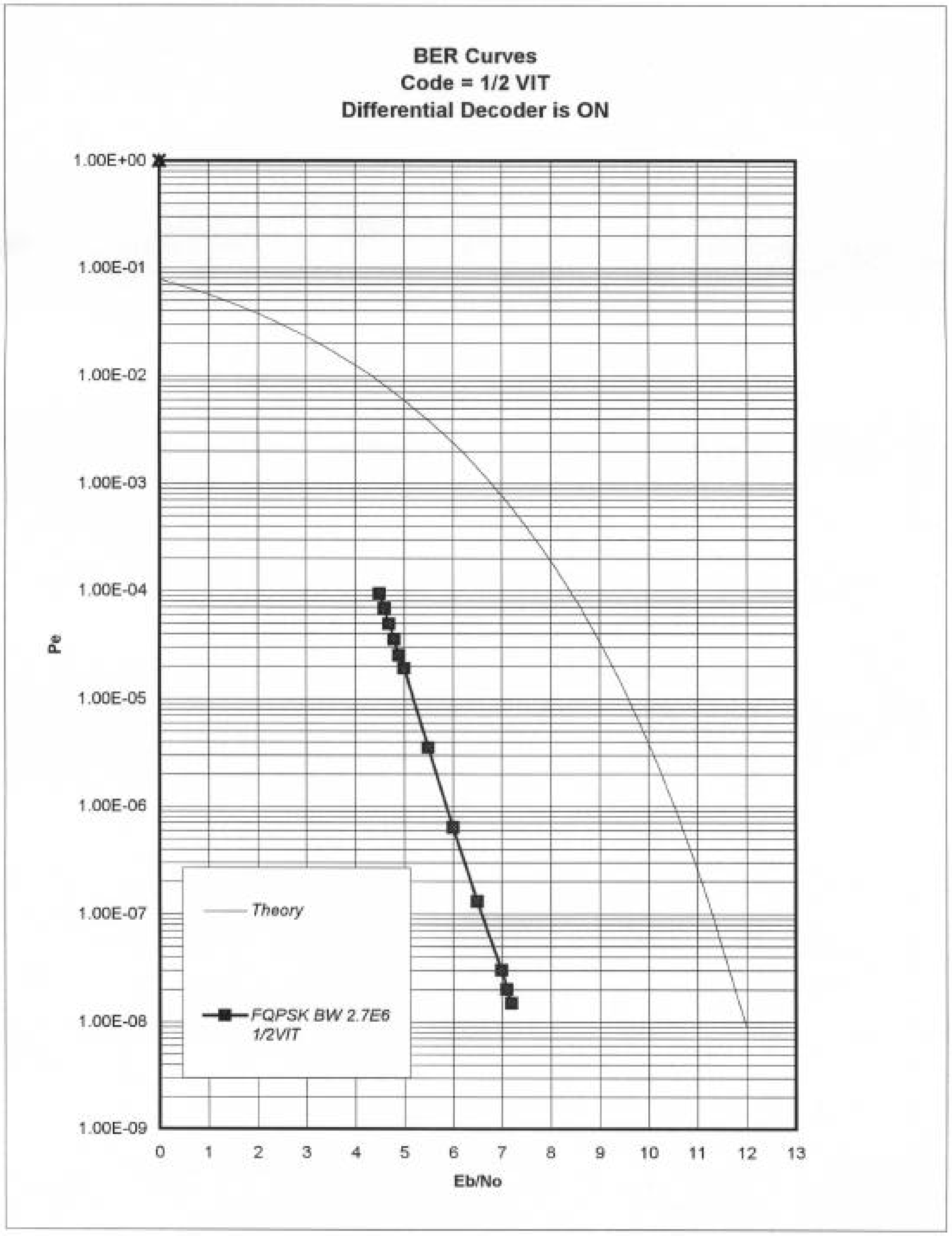
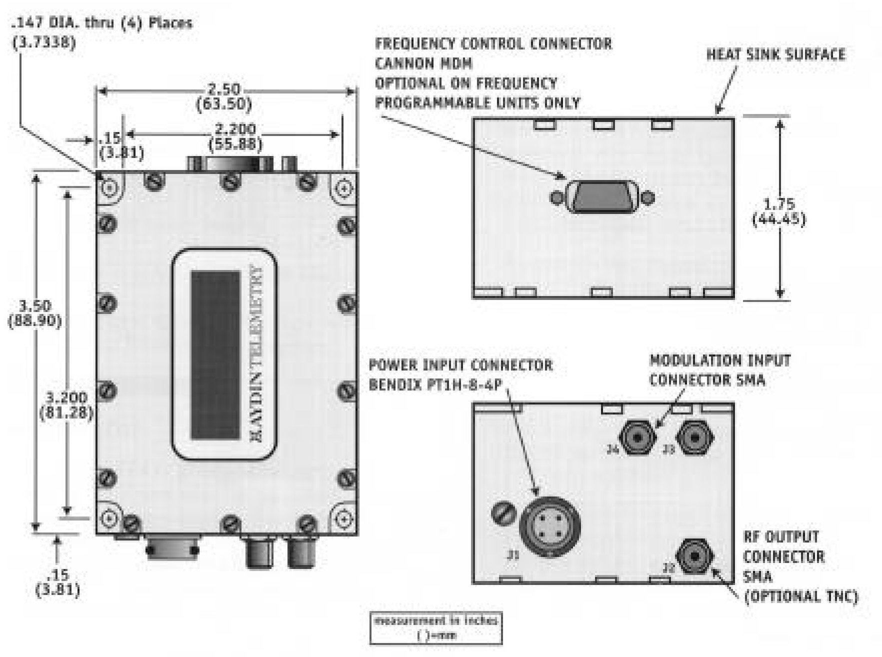


Figure 5 Measured BER performance with ½ convolutional encoder, direct modulated L Band FQPSK non-linearly amplified transceiver in an AWGN channel.

PHYSICAL DIMENSIONS



CONCLUSION

It has been demonstrated that a FQPSK implementation will increase spectral efficiency over PCM/FM by 200% while maintaining good BER performance. A frequency agile as well as a bit rate agile design can still meet the requirements for BER and DC efficiencies required today. By utilizing commercial MODEM components, a small footprint and low cost solution, typically required for missile systems, can be realized without compromising reliability or performance.

REFERENCES

[1] Feher K. et al., U.S. Patents 4,567,602; 4,644,565; 5,491,457; 4,339,724; 5,784,402, post-patent improvements and other U.S. and international patents pending. For Feher patented FQPSK and GMSK licensing and technology transfer information, contact:
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