IEEE 802.11

WIRELESS ACCESS METHODS AND PHYSICAL LAYER SPECIFICATIONS

Title:

OQPSK Modem/Radio for the Adopted DS-SS Modulation Standard

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SUMMARY

For the tentatively adopted Offset QPSK (OQPSK) Direct Sequence Spread Spectrum (DSSS) Physical Layer (PHY) standard, we recommend a set of modem/radio filter specifications and radio parameters required to meet transmit emission limits and lead to interoperable transmit and receive systems. 5.5 chip OQPSK 11 chip sequence with BPSK fallback was adopted on September 22, 1993 in Atlanta by the DS-SS committee as the 802.11 DSSS-PHY standard [Ref. 802.11-93/170].

The transmitted power spectral density has to be attenuated 30 dB and 50 dB respectively at ± 11 MHz and ± 22 MHz. To meet this stringent out-of-band attenuation requirement, conventional DQPSK or π/4-DQPSK systems would require very expensive linearized (up to 1 Watt at 2.4 GHz) amplifiers. These amplifiers could require an approximately 9 dB higher peak voltage handling capability than the 1 Watt power. Such a high voltage/power capability could be very expensive or not practical for PCMCIA card implementations. We agree with NCR's Jan Boer's findings [21] that conventional DQPSK is suitable for low power, cost-effective and small size implementations." The problem with the NCR [J. Boer, Ref. 21] and NCR/Telxon [J. Boer/P. Stuhsaker, Ref. 18] DQPSK proposal is that for higher power in the 250 mW to 1 Watt range, DQPSK spreads into adjacent channels or requires very complex and expensive linear amplifiers. Up to 1 Watt transmission is a practical requirement in an interference controlled environment. The reduced envelope fluctuation of OQPSK and constant envelope FQPSK (a subclass of OQPSK) [Ref. 1-7; 13] and [20] leads to power (and cost) efficient Nonlinearly Amplified (NLA) amplifier solutions. The importance of offset QPSK has also been highlighted in Qualcomm's product and TIA-cellular CDMA system specifications. The FH-SS committee of IEEE 802.11 decided (after many thorough investigations) that NLA-constant envelope techniques are essential for 1-Watt transmission. In the FCC-15 bands, strong external cochannel interference, including interference from FH-SS, could mandate the full 1-Watt transmission power permitted by the FCC. Most major international standards, e.g., DECT, GSM, as well as IEEE-FH-SS, concluded that constant envelope systems are required.

1. Power-Battery Efficient Nonlinear Amplifier (NLA): An Essential Requirement

- High power, e.g., 250 mW, 500 mW and 1000 mW (1 Watt), is an essential practical requirement in an interference controlled environment such as "FCC-15" at 2.4 GHz or 900 MHz.

- In the same band, location, or time, other interferers such as FH-SS (IEEE 802.11 standard), IVHS transmitters, microwave ovens, and other non-standardized radio transmitters transmit 1 Watt. Thus, the DS-SS transmitter is also required to transmit up to 1 Watt. With less transmit power, performance, coverage, throughput, message delay are all degraded.

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2. DQPSK is NOT suitable for high (more than 250 mW) power PCMCIA/miniaturized implementation at 2.4 GHz

- Previous proposals to adopt conventional DQPSK by NCR and Telxon [J. Boer, P. Stuhsaker, Ref. 18 and 21] are suitable for "**low power**, cost effective and small size implementations" [Ref. 21; NCR]. In the 2.4 GHz band we assume "low power" is in the 100 mW range.

- For required high power applications in the 250 mW to 1 Watt range, the filtered DQPSK 5-10 dB envelope fluctuation could require a "peak handling capability" of 10 Watts. This does not seem practical. Filtering is required to meet the spectral mask, already adopted based on the NCR/Telxon proposal [Ref. 18].

- Without expensive, larger amplifiers and sophisticated linearizers, the DQPSK spectrum is restored and exceeds the specified spectral mask by 15-30 dB; see Figure 1.

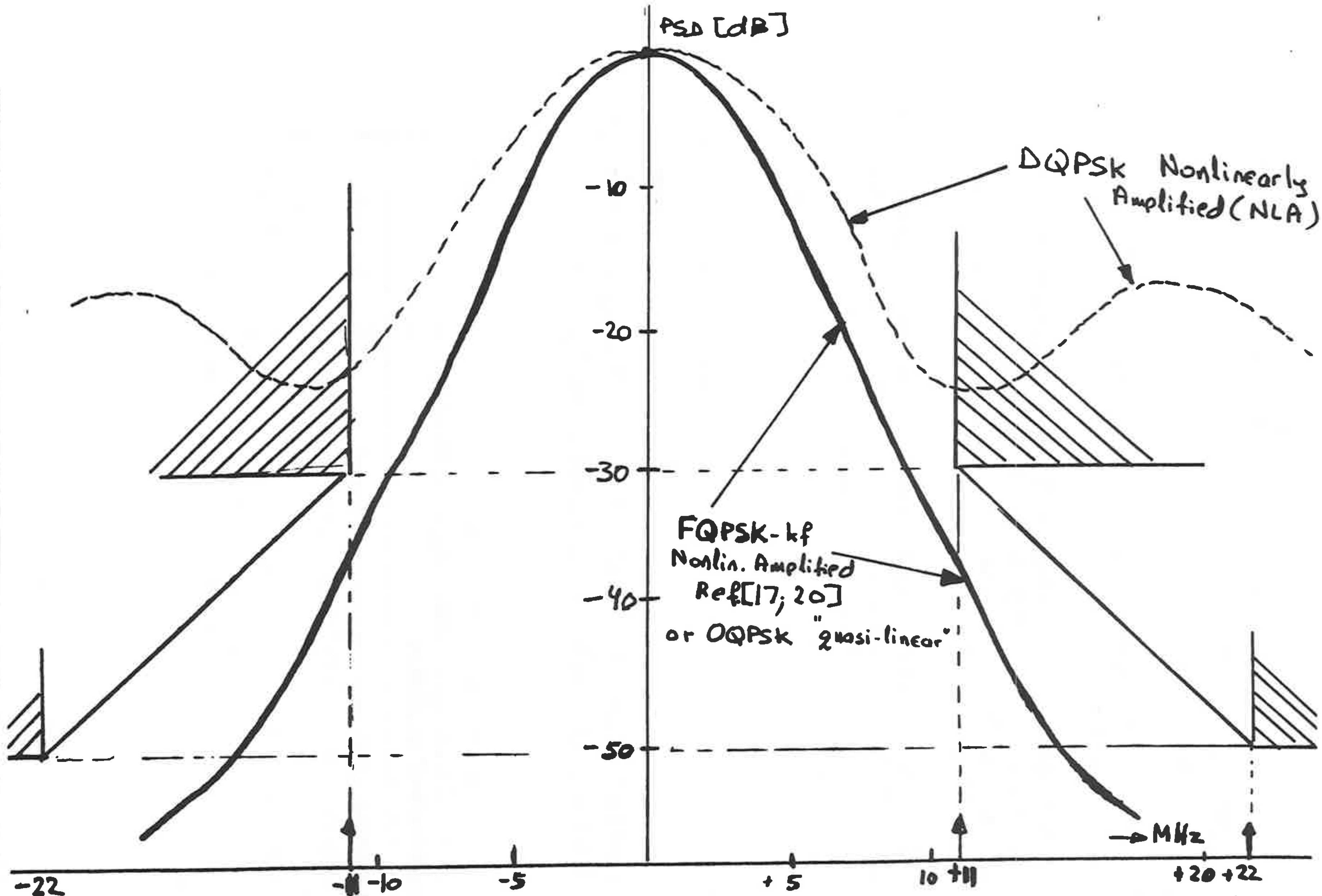

Fig. 1.1 DS-SS spectral mask for 11 Mc/s of an I and Q quadrature QPSK system for 2 Mb/s data each at 11 chips/symbol. (a) Dotted line NLA (nonlinearly amplified) DQPSK (premodulation filtered). (b) FQPSK-(KF) spectrum-nonlinearly amplified per Ref. [20].

3. Very expensive linearized 1 Watt (up to 10 Watt peak?) amplifiers could be required to limit the DQPSK spectrum within the specifications

- In Fig. 1.1, the adopted standard frequency mask- and forbidden regions are illustrated.
- NLA (nonlinearly amplified) or "C-class" amplified spectrum of a conventional filtered DQPSK signal, 11 Mchips/second per I and Q channels for the standardized 2 Mb/s data rate requirement exceeds the spectral limit of 15-30 dB.
- OBO (Output Backoff) requirement to have linearized operation is in the 5-10 dB range in the U.S. digital cellular industry. For the more stringent IEEE DS-SS mask, a conventional amplifier could require more than 10 dB OBO.

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4. Output Backoff (OBO) for DQPSK is even larger than for π/4-DQPSK illustrated in Table 1

OBO required to avoid spectral regeneration of π/4-DQPSK filtered signals, assuming ideal linearized "soft-limited" amplifiers	1.5 – 2.5 dB
Additional OBO required due to non-ideal (nonlinear-soft-limited) RF amplifiers	2 – 4 dB
Additional OBO due to gain variations and gain setting level changes/output power variations	1.5 – 2.5 dB
Total output backoff (OBO) required	5 – 9 dB

Table 1. Output backoff (OBO) requirements for π/4-DQPSK linearly amplified wireless systems. From Ref. [12].

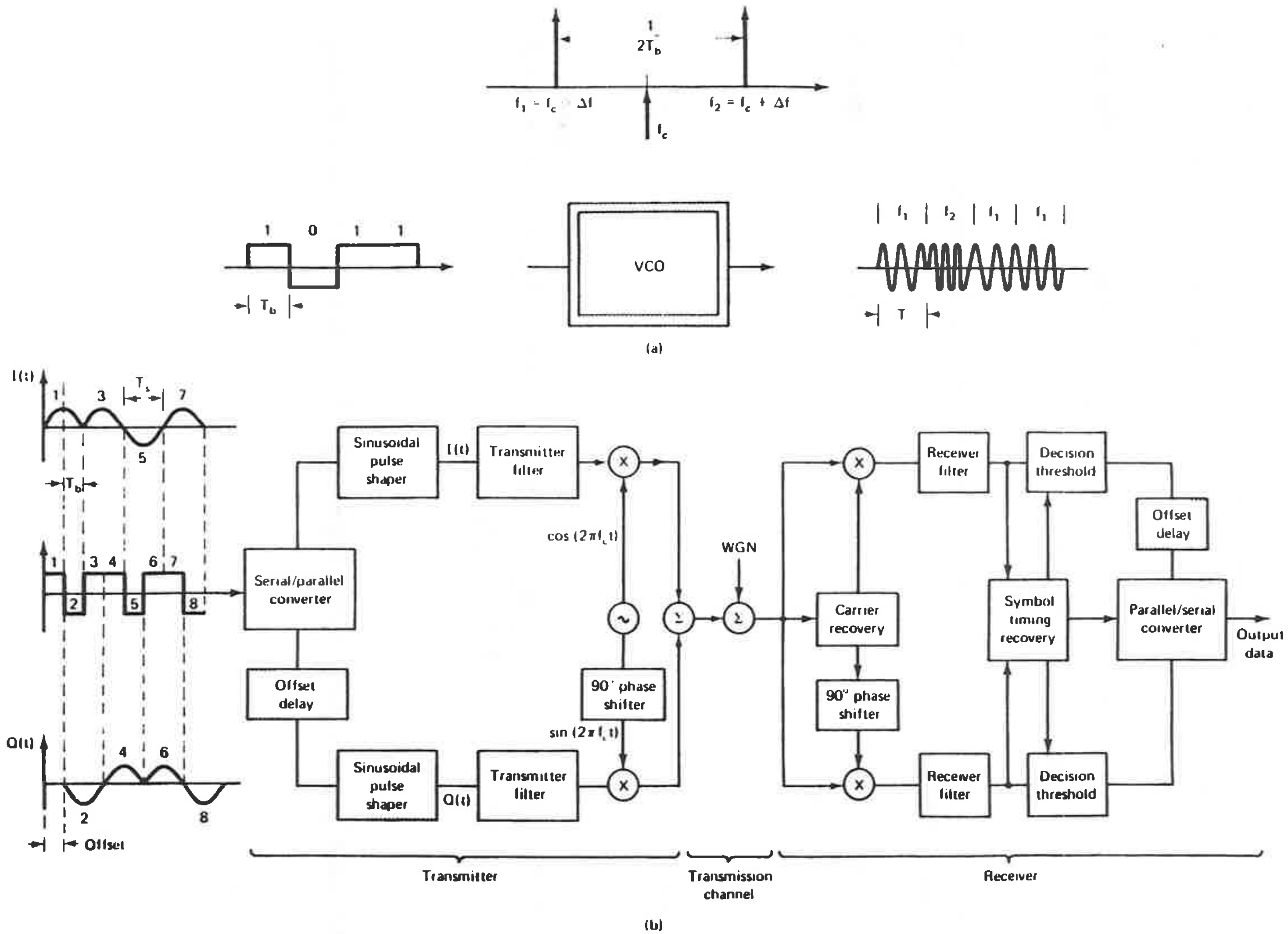

Fig. 1.2 **MSK and OQPSK (offset QPSK) equivalence. The FQPSK-nonlinearly amplified NLA increased spectral efficiency modem/radio systems are a subclass of conventional OQPSK.**

5. Offset QPSK (OQPSK) and Compatible FQPSK Nonlinearly (C-class) Amplified Solution

- The NLA (nonlinearly amplified) constant envelope **FQPSK-kf** spectrum is within the frequency mask [17; 20] and provides a cost and power efficient solution.
- OQPSK in general has smal envelope fluctuation. OQPSK and FQPSK are compatible solutions.
- OQPSK can meet the spectral mask with smaller amplifiers than conventional DQPSK.
- FQPSK-kf provides the most power efficient nonlinearly amplified solution. It is a patented technology; see [5; 20].

6. OQPSK-MSK-FQPSK Equivalence: Coherent and Differential Demod Capability

- In Figure 1.2 the equivalence of OQPSK and MSK is illustrated.
- FQPSK family is a constant envelope OQPSK; it is also equivelent with MSK.
- Coherent and differential demodulation possible.
- CYLINK presentation of DSSS is on MSK.
- QUALCOMM and EiA/TiA cellular TiA standard is offset QPSK; see Figure 1.3.
- Cellular industry and others can have offset QPSK—we can have it also.

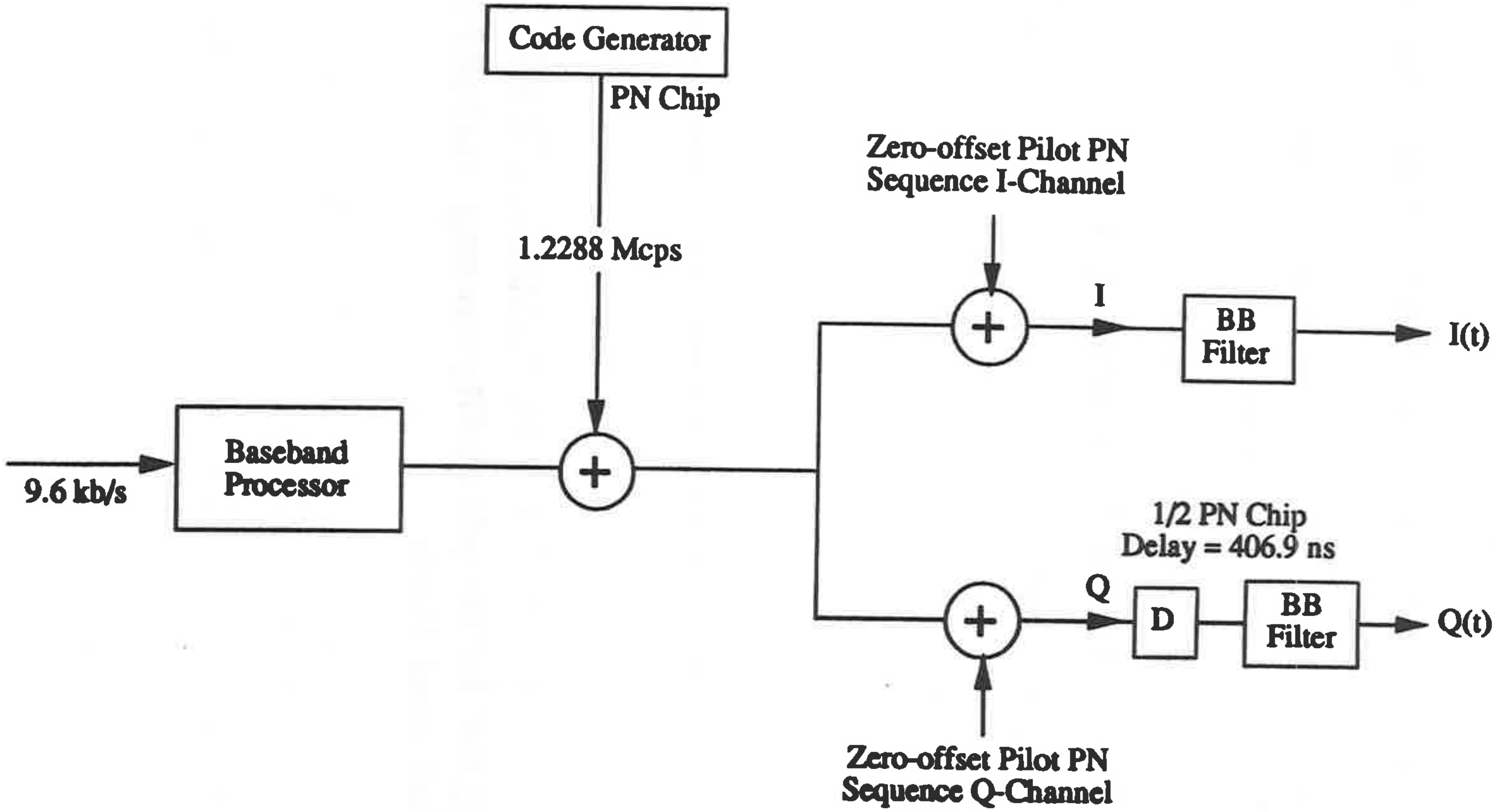

Fig. 1.3 Qualcomm, Inc. proposed and EIA/TIA adopted CDMA standard DS-SS subscriber unit to base station-reverse link OQPSK modulation process of the EIA/TIA wideband spread spectrum digital cellular system standard TR 45.5, April 21, 1992. Based on Ref. [22].

7. Chip and ASIC OQPSK and MSK Demodulators for Spread Spectrum (Coherent/Differential)

To the best of our knowledge the following companies already have VLSI and ASIC chips (a partial list):

- UNISYS: Type PA-100 for QPSK, OQPSK, FQPSK, MSK DS-SS coherent/differential demodulation.
- CYLINK: MSK (note equivalence with OQPSK).
- QUALCOMM: for cellular DS-SS CDMA standard
- NTT, Japan: for several applications [17]
- California Microwave
- Harris
- COMSAT

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8. Tx and Rx Filtering—<u>Recommended Strategy</u> for Interoperability among various DS-SS Manufactured Units

- Transmit spectrum (Tx) defined combination of Tx filter with impact of amplifier if any. See spectral mask, Figure 1.1.
- Receive filter a simple 4th-order Butterworth or "square root of raised cosine" with $\alpha \leq 1$ could be specified.
- Detailed filter masks could be prepared (for best interoperability) for next meeting (January 1994).

9. REFERENCES

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