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February 16, 2001

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

Magalie Roman Salas, Esq.
Secretary
Federal Communications Commission
445 Twelve Street, S.W., Room TWB204
Washington, D.C. 20554

Re: **Intersil Corporation**
***Ex Parte* Meeting**
Amendment of Part 15 of the Commission's Rules Regarding Spread Spectrum Devices, ET Docket No. 99-231

Dear Ms. Salas:

On behalf of Intersil Corporation ("Intersil") and pursuant to Section 1.1206 of the Commission's Rules, I am writing to report an *ex parte* meeting on February 15, 2001, with the Commission regarding the above-referenced matter. Participating in the meeting were Kenneth Nichols, Chief of the Commission's Columbia Laboratory, and Richard Fabina, David Means, Raymond LaForge, and Joe Dichoso, also of the Commission's Columbia Laboratory. In attendance on behalf of Intersil were Dennis Eaton, Mark Webster, and Jim Zyren, of Intersil, and Nancy Killien Spooner of Swidler Berlin Shereff Friedman.

Intersil met with members of the Commission's Columbia Lab to describe the advantages of Orthogonal Frequency Division Multiplexing (OFDM) for use in Wireless Local Area Network (WLAN) applications. Intersil provided staff with a written communication in support of its position, a copy of which is attached to this letter. At the request of staff, Intersil hereby includes a copy of this submission in the above-referenced docket.

Intersil is a strong proponent of the use of OFDM for WLAN applications. OFDM offers a robust, widely adopted technology that is well suited for transmission of high speed data in challenging multipath and interference environments. Going forward, OFDM would be well suited for use in WLAN applications, regardless of the band of operation. As described in the attached written submission, OFDM provides excellent performance in the presence of narrowband interference, such as that encountered in the presence of Bluetooth devices. The ability to withstand interference is highly desirable for technologies deployed in unlicensed bands.

OFDM has already been adopted for use in the 5 GHz bands for IEEE 802.11a and HiperLAN2 WLAN applications. Permitting further use of this compelling and widespread technology in the future will result in more rapid deployment of WLAN technology in all bands in which it is used, thus benefiting both industry and consumers.

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List A B C D E

Intersil also separately takes this opportunity to respond to an *ex parte* submission filed by Texas Instruments on December 14, 2000. In that filing, Texas Instruments asserted that the Complimentary Code Keying (CCK) waveform adopted for mandatory use in the IEEE 802.11b protocol does not comply with the Commission's rules for Direct Sequence Spread Spectrum (DSSS) systems. As described more fully below, Intersil disagrees with this assertion.

In contrast to claims made by Texas Instruments in its December 14, 2000, *ex parte* filing, the CCK waveform is fully compliant with the Commission's Rules for spread spectrum systems. CCK uses a family of spreading codes which increase the bandwidth of the transmitted signal by a factor of 8:1, thus providing 9 dB of spreading gain. Some of the information is included in the spreading code, as explicitly permitted in the Commission's definition of a Spread Spectrum System:

> A spread spectrum system is an information bearing communications system in which: (1) Information is conveyed by modulation of a carrier by some conventional means, (2) the bandwidth is deliberately widened by means of a spreading function over that which would be needed to transmit the information alone. (In some spread spectrum systems, a portion of the information being conveyed by the system may be contained in the spreading function.)

47 C.F.R. § 2.1. Note that CCK uses a high speed spreading code as explicitly required in the Commission's definition of a Direct Sequence System (also contained in section 2.1 of the Commission's Rules, 47 C.F.R. § 2.1), which is:

> A spread spectrum system in which the carrier has been modulated by a high speed spreading code and an information data stream. The high speed code sequence dominates the "modulating function" and is the direct cause of the wide spreading of the transmitted signal.

As the name implies, the Packet Binary Convolutional Coded (PBCC) waveform described by Texas Instruments employs a convolutional code. Thus, unlike CCK, it does not employ a spreading sequence. While PBCC may claim to have coding gain, it may not properly claim to have any spreading gain. By comparison, in addition to the 9 dB of processing gain with results from the use of a spreading code, CCK has approximately 2 dB of coding gain. CCK has a total of 11 dB of processing gain, thus complying with the processing gain requirement in section 15.247 of the Commission's Rules, 47 C.F.R. § 15.247:

$$\begin{aligned} \text{Processing gain} &= \text{spreading gain} + \text{coding gain} \\ &= 9\text{ dB} + 2\text{ dB} \\ &= 11\text{ dB} \end{aligned}$$

In its *ex parte* filing of December 14, 2000, Texas Instruments asserted that PBCC-11 enjoys 3 dB better performance over CCK in Additive White Gaussian Noise (AWGN). Further, Texas Instruments claims that this benefit is derived from "superior coding gain." Intersil makes the following observations:

1. Performance in AWGN is not described in the Commission's definition of Spread Spectrum Systems, the definition of Direct Sequence Systems, or in section 15.247 of the Commission's Rules.

2. As described above, PBCC employs a convolutional coding scheme. It does not employ a spreading code. While PBCC does possess coding gain, it does not have any spreading gain.

3. In AWGN, spreading gain provides no performance benefit over non-spread systems. CCK thus derives no benefit from its use of spreading codes in AWGN. Taking Texas Instruments' claims at face value, PBCC has 3 dB better performance in AWGN relative to CCK. However, PBCC cannot make any claim to true spreading gain. It can therefore be shown that PBCC has a total of 5 dB of processing gain, composed entirely of coding gain (3 dB better than CCK), and having no spreading gain.

Based on the foregoing discussion, it should become clear that:

1. CCK complies with the Commission's definition of a Spread Spectrum System;

2. CCK complies with the Commission's definition of a Direct Sequence System;

3. CCK complies with the Commission's requirement that DSSS systems must have a minimum of 10 dB of processing gain, as described in section 15.247 of the Commission's Rules.

In contrast, PBCC meets none of these criteria. Texas Instruments does claim that PBCC meets the Commission's requirement for 10 dB of processing gain. However, in order to reach this conclusion, Texas Instruments employs definitions of spread spectrum[1] and processing gain[2] entirely of its own making which bear no relation to the Commission's current Rules. In addition, the claimed benefits of PBCC in AWGN do not translate into "real world" performance advantages.

In practice, WLAN communications channels are limited by multipath and interference, rather than AWGN. As shown in greater detail in the attached slides, the CCK waveform has inherent properties which render superior performance in the presence of multipath. In addition, OFDM is far superior to PBCC in terms of narrowband interference immunity. In conclusion, Intersil reiterates its support for OFDM's use in WLAN applications, due to its significant advantages.

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[1] *Ex Parte* Filing of Texas Instruments in ET Docket 99-231, December 14, 2000, at Slides 15, 16.
[2] *Id.*, at Slides 22, 23.

Please date-stamp the extra copy of this letter and return it in the enclosed envelope. If you have any questions regarding this filing, please contact the undersigned.

Very truly yours,

James Zyren

James Zyren
Director of PRISM/Work Products
Intersil Corporation

cc: FCC's Columbia Lab:
Kenneth Nichols
Richard Fabina
David Means
Raymond LaForge
Joe Dichoso

Issues Concerning Wireless LAN's in the 2.4 GHz ISM Band

Mark Webster
Jim Zyren
Dennis Eaton
Steve Halford

Feb.15, 2001

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Address 3 Topics

1. Coding gain is not equivalent to processing gain?
2. Examine the equivalence of single-carrier and multi-carrier (OFDM) systems
3. Where do we go from here?
   - Waivers for individual systems?
   - Revision of rules (NPRM)?

TOPIC 1

Is Coding Gain Equivalent to Processing Gain?

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Is Coding Gain the Same as Processing Gain?

- Coding gain is NOT EXACTLY the same as processing gain.
- 15.247(e) "The processing gain of a direct sequence system shall be at least 10 dB. ... "
- The intent of 15.247 seems to be a requirement for DSSS systems to
  - Maximize receiver robustness-to-interference.
  - Minimize transmitter interference-to-others.
- AWGN performance is an inadequate measure or figure-of-merit to satisfy the intent of 15.247 (require robust systems).
- To increase data rates, recently attempts have been made to argue that coding gain is a direct measure of processing gain.
  - This section shows this argument may be too simplistic.

Coding Gain is Narrowly Defined

- Coding gain is measured using only additive white Gaussian noise (AWGN).
  - Constant noise spectrum which is broader than signal of interest
  - Constant variance (or power over a packet)
- However, actual signal interference can be quite different from AWGN
  - Interference bandwidth may be narrower
  - Interference may have dynamic variance (power)
- Multipath interference can be quite different from AWGN
  - Multipath interference is a major impairment for high-data-rate systems
- Processing gain is measured in the presence of interference.

Coding Gain in AWGN : PBCC vs. CCK

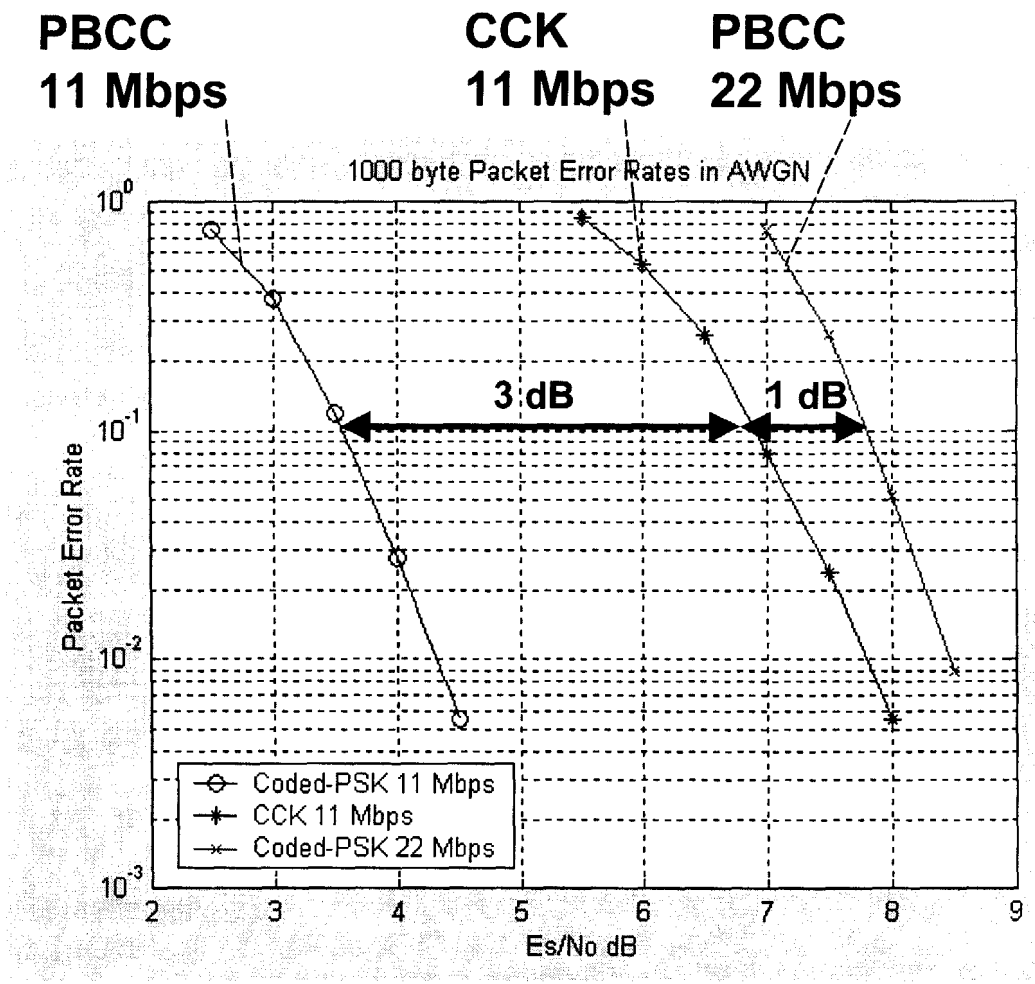
In AWGN vs. Es/No

- 11 Mbps PBCC is 3 dB better than CCK
- 22 Mbps PBCC is 1 dB worse than CCK

Key Question

Does superior coding gain in AWGN translate to superior performance in realistic interference environments?

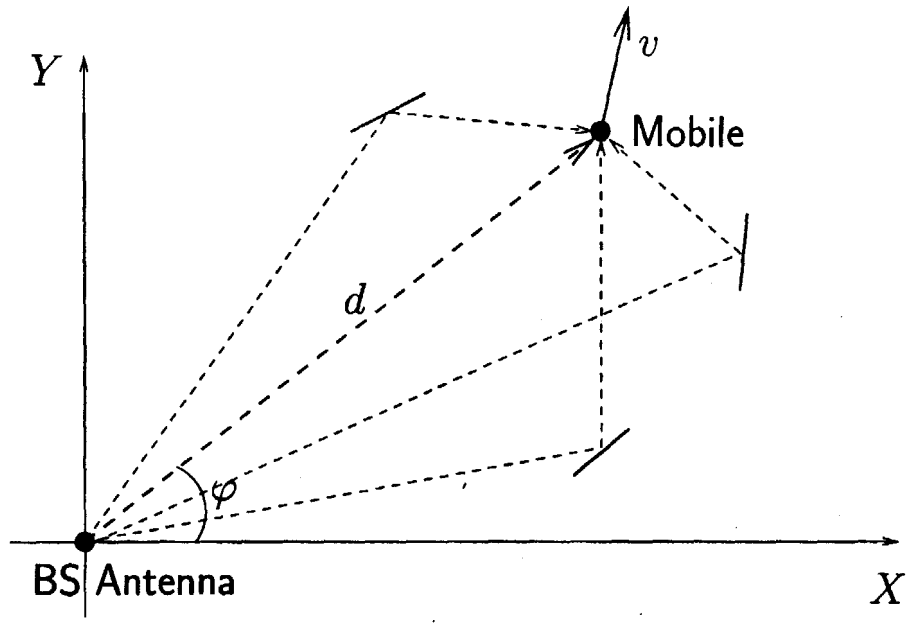
NO! Real world is limited by multipath and interference. See next slide.



Multipath is Self-Interference

Multipath

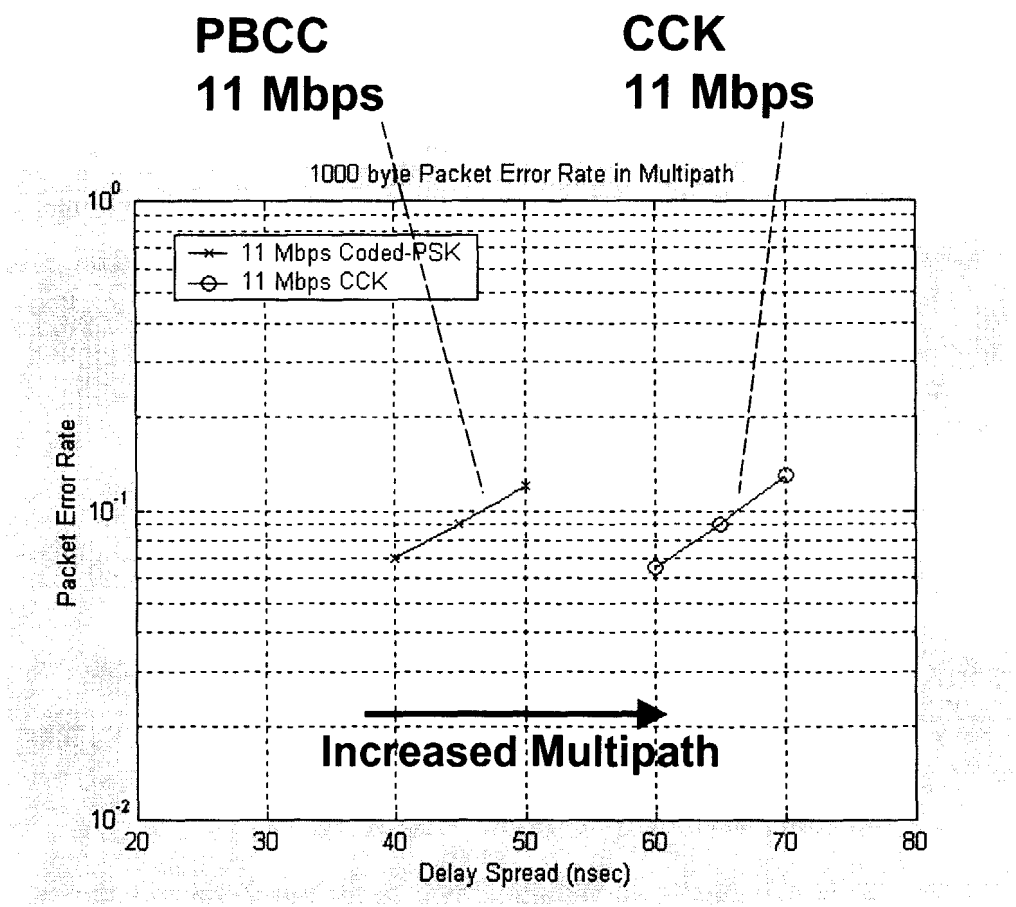
- Multiple signal paths are received.
- Each path results from a reflection.
- Each path can act as an interferer.



Multipath channel seen at location (d, φ)

PER for 11 Mbps Systems in Multipath with No Equalizer

- Raw CCK out-performs raw PBCC in multipath self-interference
- Superior coding gain of PBCC in AWGN did not translate to superior multipath performance (real world)



Channel Matched Filter Receiver w/o Equalization
Exponential Fading channel with 1 sample/chip

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Real World Interference & Burst Noise

- **Coding gain does not necessarily translate into interference immunity.**

- **Burst Errors will occur in a W-LAN environment**
  - **Microwave ovens, photocopiers, & BlueTooth will generate bursts of interference**
  - **Duration typically 220 nSecs (photocopier) & 16 ms for microwave*** 1**

- **OFDM distributes information across multiple orthogonal sub-carriers**
  - **OFDM is highly resistant to narrowband interference (e.g., BLUETOOTH)**

*** 1 K. Blackard, T. Rappaport, & C. Bostian, "Measurements and Models of Radio Frequency Impulsive Noise for Indoor Wireless Communications," IEEE Journal on Selected Areas in Communications, Vol. 11, No. 7, pg. 991 -1001, September 1993.

Coding Gain in AWGN: PBCC vs. OFDM

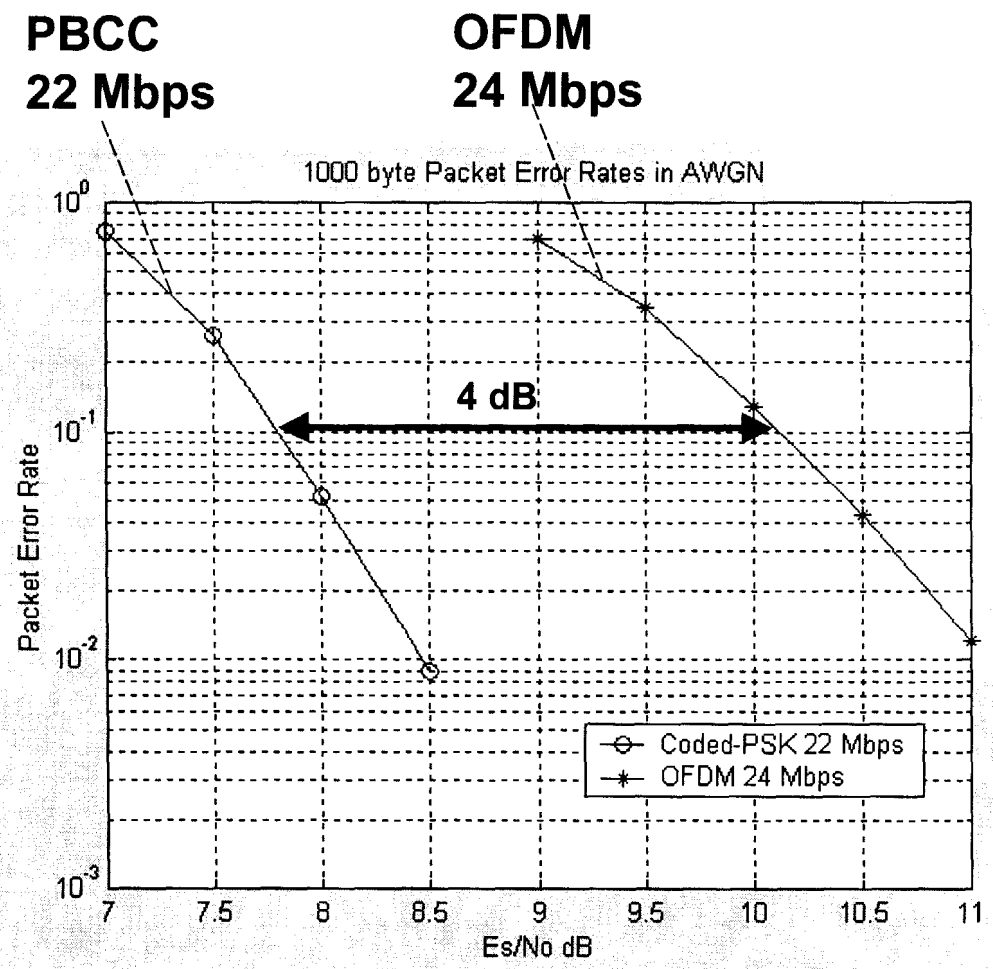
In AWGN vs. Es/No

22 Mbps PBCC
is 4 dB better than
24 Mbps OFDM

Key Question

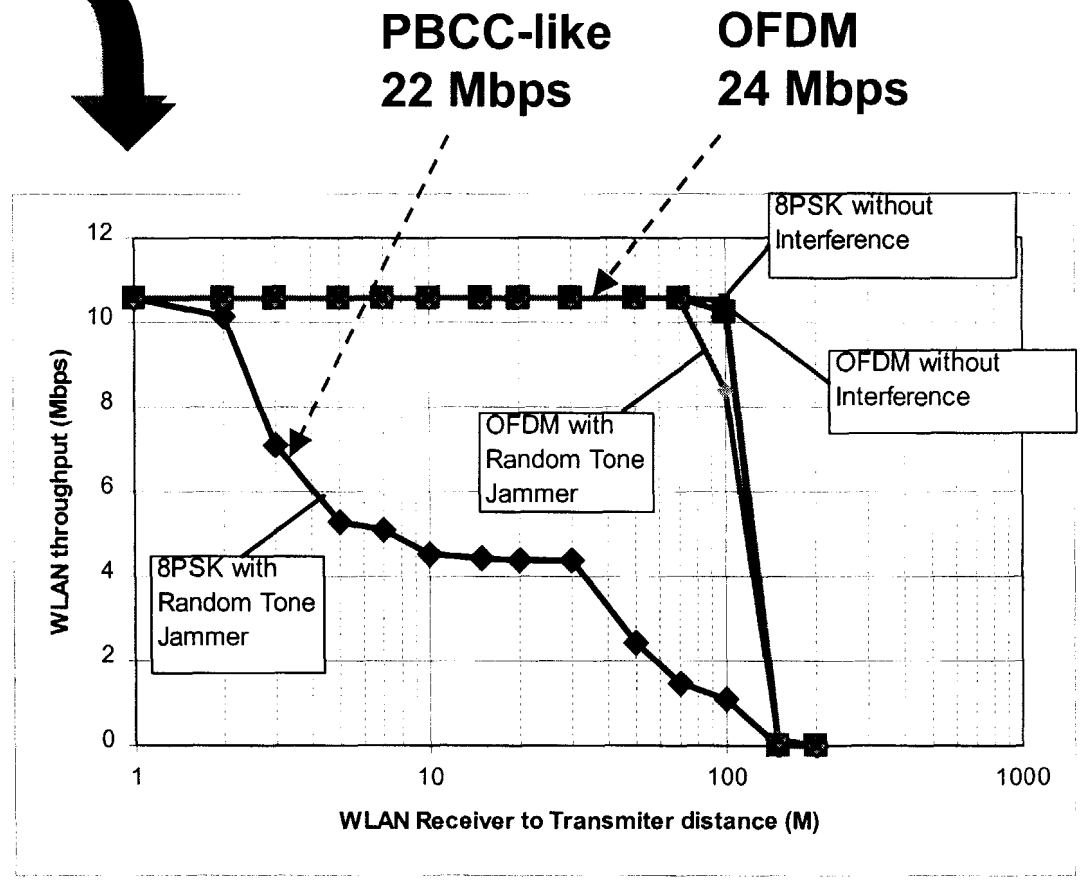
Does superior coding gain in AWGN translate to superior performance in realistic interference environments?

NO! See next slide.



PBCC Performance is Sensitive to BlueTooth Interference

E. Zehavi (**Mobilian**), et al (IEEE documents IEEE802.11-01/061r0 & IEEE802.15-01/066r0) showed that the throughput of coded 8-PSK w/o an interleaver was very sensitive to the presence of a BlueTooth interferer.



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Topic 1 Conclusion

- Coding gain performance in AWGN does not necessarily translate to realistic interference environments.
  - Does not consider multipath.
  - Does not consider modulated narrowband interference.

- Public comment is needed to illuminate all technical issues.
  - NPRM?
  - Industry Forum?

TOPIC 2

Equivalence of Single-Carrier and Multi-Carrier Systems

Single-Carrier and Multi-Carrier Systems Can be Equivalent

- No significant distinction exists between single-carrier and multi-carrier systems.
- Example: Demonstrate that 11 Mbps CCK can be synthesized using OFDM techniques.
- There should be no regulatory distinction between single-carrier and multi-carrier systems.

Time-Domain versus Frequency-Domain

- Signals can be analyzed in either the time-domain or the frequency-domain using Fourier theory.

- Signals can constructed in either the time domain or the frequency domain
  - FSK is easily conceptualized in the frequency domain
  - QPSK is easily conceptualized in the time domain

- Submission IEEE 802.11-00/202 showed that *ALL* 802.11b mandatory signals (1,2,5.5 and 11 Mbps) can be generated/received using an OFDM modulator and demodulator.

- This section describes how 802.11b 11 Mbps CCK can be generated using an OFDM modulator and received with an OFDM demodulator.

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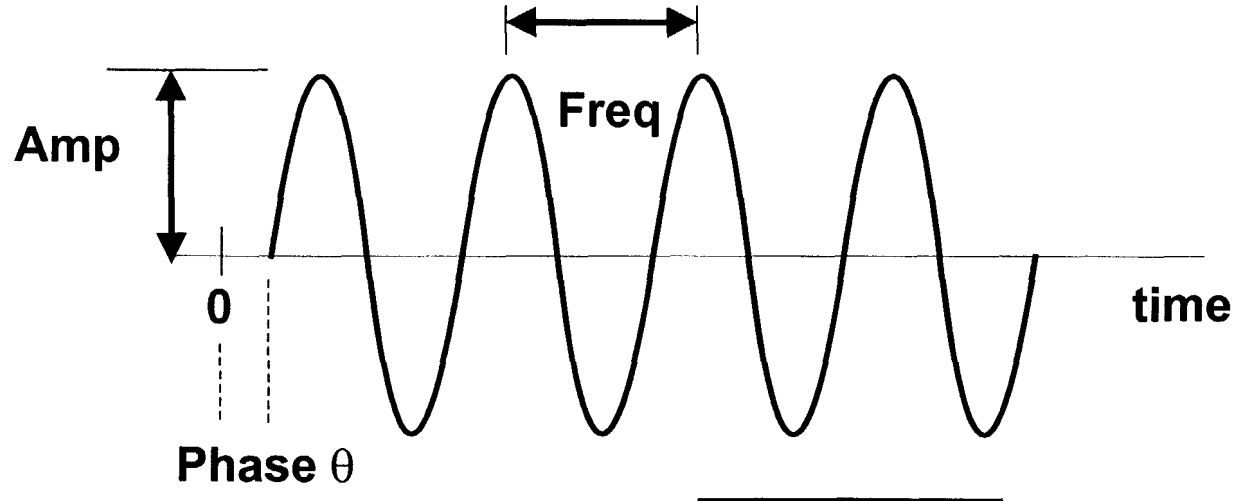
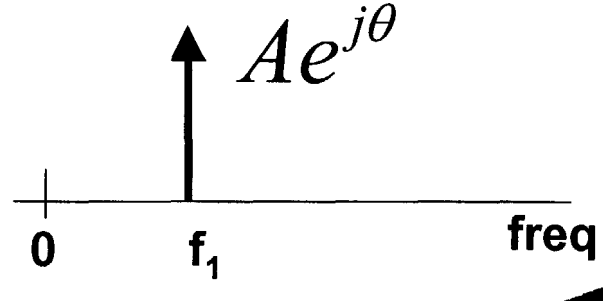
Amplitude-Phase Modulated Sinewaves

Sinewave's 3 Parameters: frequency, amplitude, phase

TIME DOMAIN



FREQ DOMAIN



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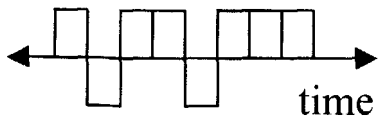
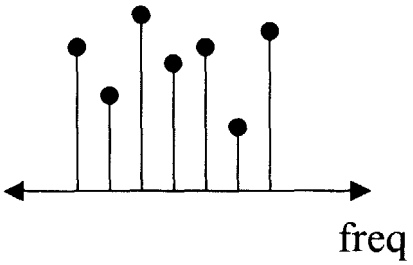
11 Mbps CCK: Single-Carrier and Multi-Carrier

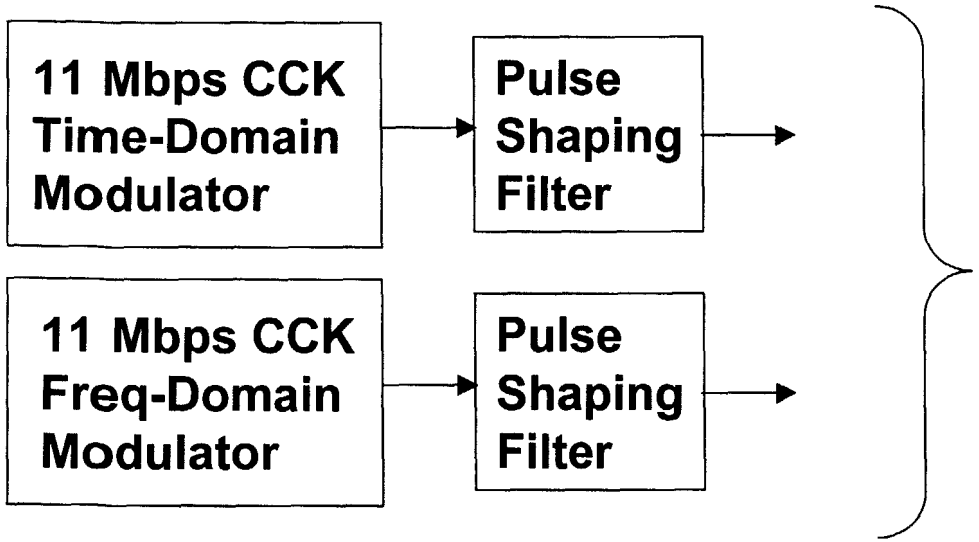
Blocks of 8 chips



Fast Fourier Transform

8 Spectral Lines





Identical Outputs

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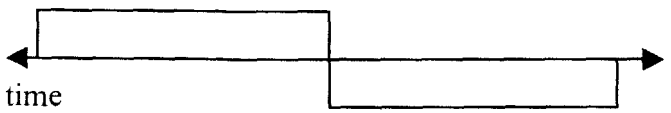
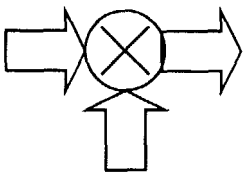
11 Mbps CCK: Time Domain Modulator

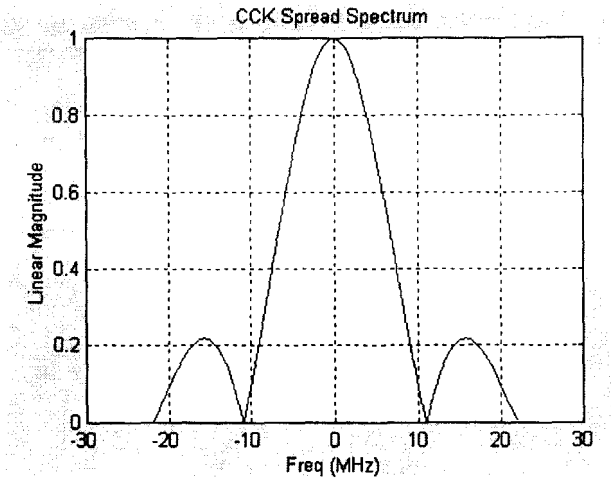
2 Info Bits

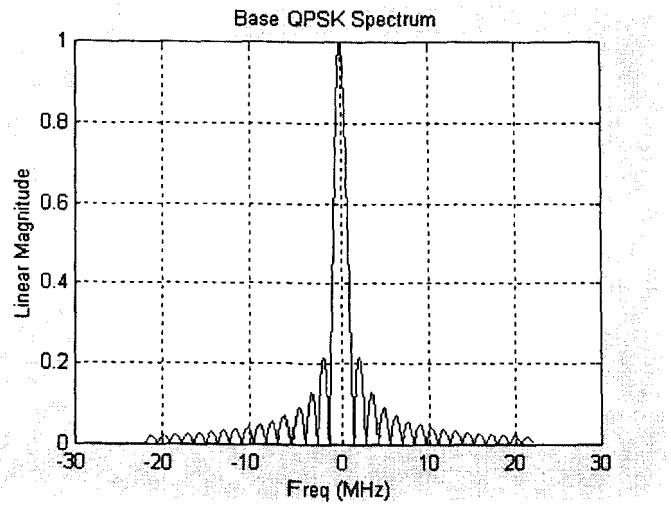
QPSK

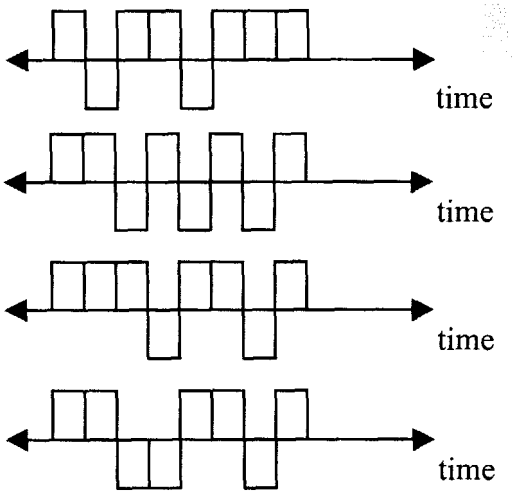


Time Domain Multiply (spread)



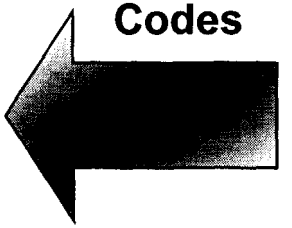






8 chips

64 Spreading Codes



6 Info Bits

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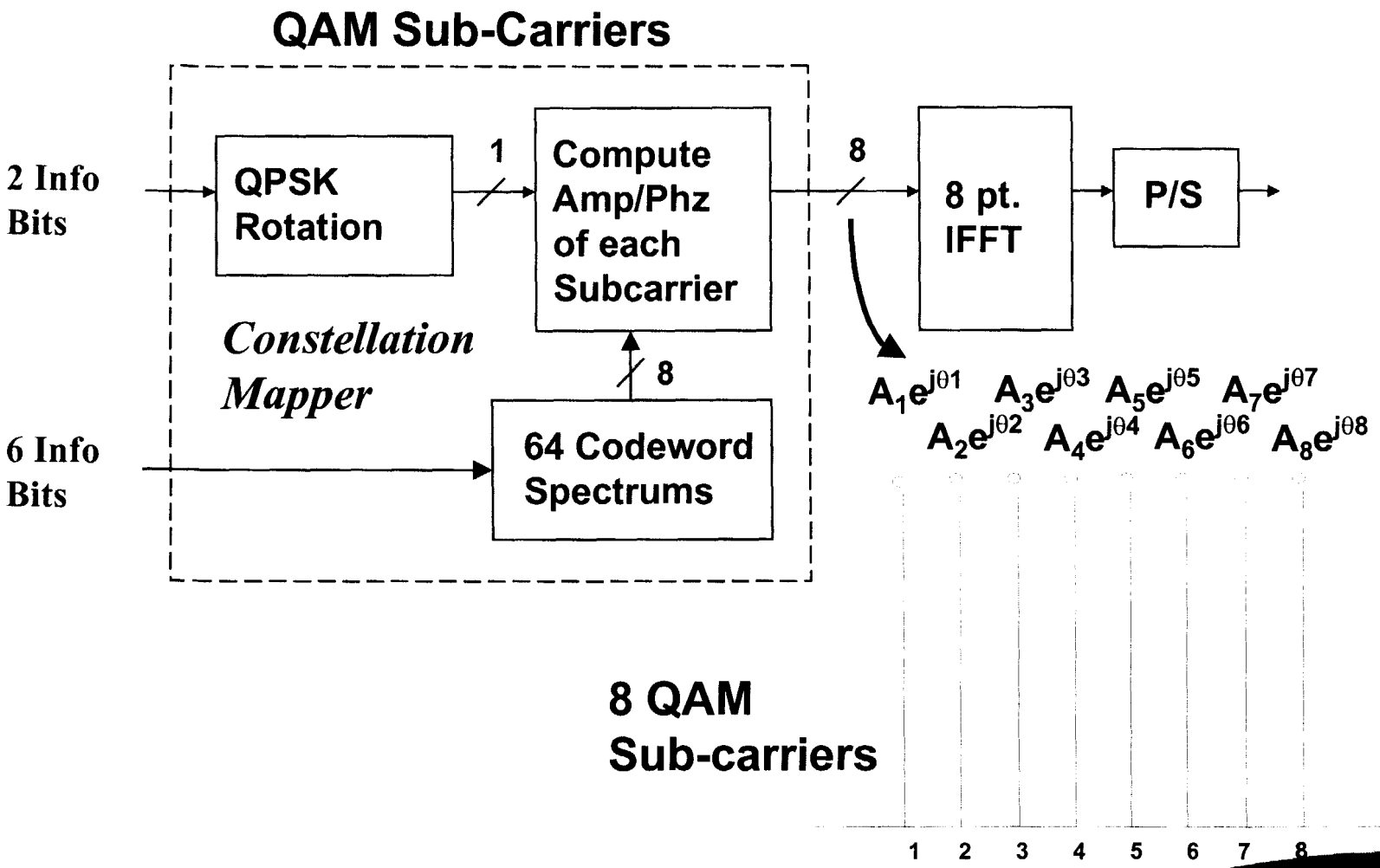
11 Mbps CCK: Frequency Domain Modulator

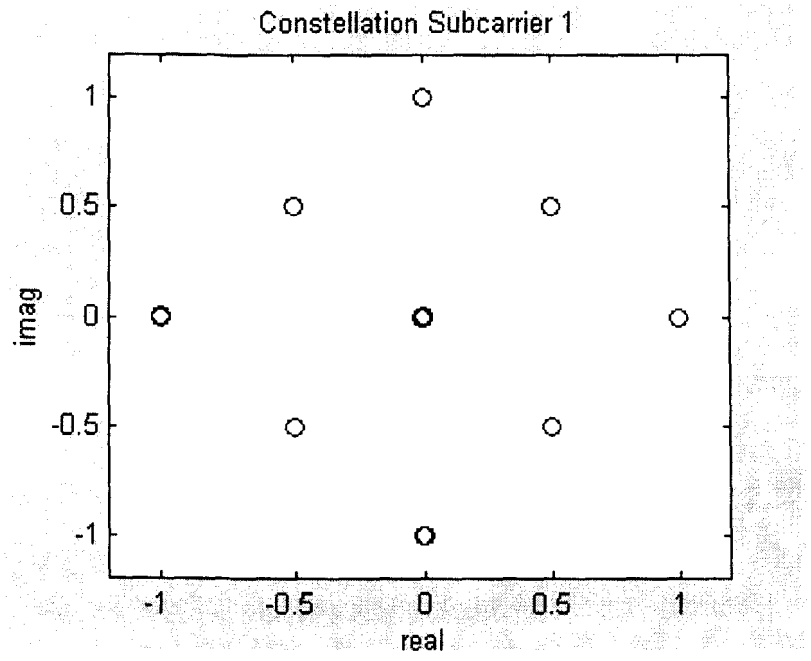


8 QAM Sub-carriers

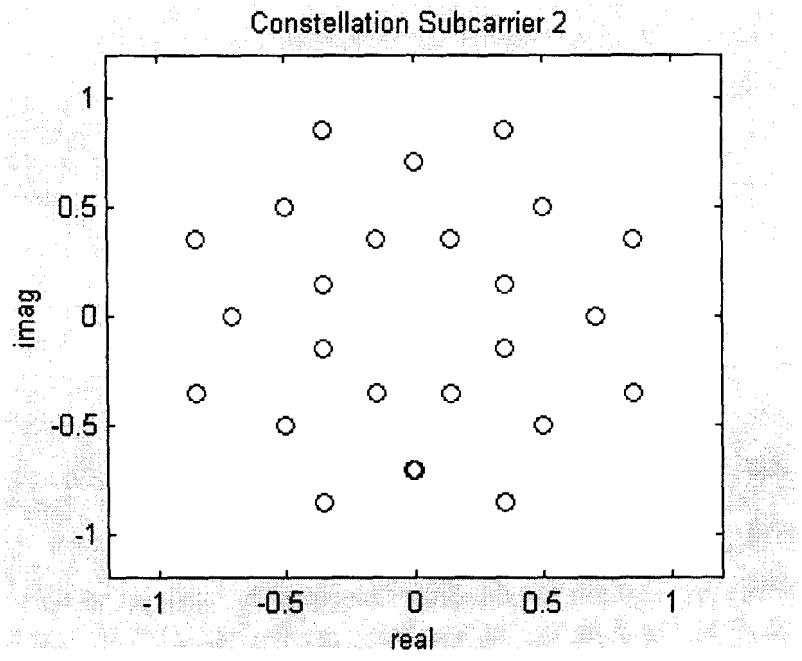
11 Mbps CCK Sub-Carrier Constellations

QAM Constellations

Sub-Carriers 1, 3, 5, 7



Sub-Carriers 2, 4, 6, 8



Topic 2 Conclusion

- There is no fundamental difference between single-carrier and multi-carrier systems.

- Systems should not be granted or denied regulatory approval based solely on whether they are single-carrier or multi-carrier.

- Equipment authorization should be granted based upon compliance with commission's definition of spread spectrum and measure of processing gain.

TOPIC 3

Where do we go from here?

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Where do we go from here?

- Industry needs clear, unambiguous rules!

  - There is a lot of confusion regarding terminology and definitions

- Is industry served by receiver testing?
  - Should we restrict issues to transmitted waveform?

- UNII rules are simple, effective, and enforceable
  - Transmit PSD limit
  - Total power limit

- Rules need clarification
  - Continuing controversy/ambiguity does not serve industry or consumers

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