Further Considerations for Implementation of Adaptive Data Rates

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1

Goals for next generation of WLANs

- Higher speed
- Compatibility with existing systems
- Universal applicability to variety of platforms

2

Higher speed

- Operate in ISM band
- Channel data rate of up to 20 Mbps
- Direct sequence spread spectrum operation compliant to FCC rules

3

Compatibility with existing systems

- Minimal modification to existing protocol software implementation
- Seamless operation in a mixed environment, i.e., present IEEE 802.11 and new high speed version

4

Universal applicability to variety of platforms

- Low power consumption
- Low cost
- Trade-off between cost/power consumption/data rate

5

Current IEEE802.11 system

- Physical Layer
  - Current system uses 11 chip Barker code as spreading code
  - Each data bit spread by entire code sequence
  - (RF) Modulation is BPSK or QPSK
  - Data rate varied by changing modulation method
  - Chip rate is 11 Mcps
  - RF bandwidth is 22 MHz
- Packet Structure
  - Well defined fields (sync, set-up, data, etc)
  - CRC protection of select fields

6

Proposed system description

- Spreading sequence
- Stacked carrier principle
- Transmitter block diagram
- Increased data rate method
- Data rates
- Variable data rate method
- RF signal bandwidth
- RF and despread signal constellation
- Coexistence and interoperability
- Interoperability scenario
- System complexity

7

Spreading sequence

- IEEE 802.11 spreading code is the 11 bit Barker Code:
  +1 -1 +1 +1 -1 +1 +1 +1 -1 -1 -1
- The augmented Barker code appends a '-1' chip at the end
  +1 -1 +1 +1 -1 +1 +1 +1 -1 -1 -1 -1
- The augmented Barker code set uses all phases of the original Barker code and appends a '-1' chip at the end
  - Code 1: +1 -1 +1 +1 -1 +1 +1 +1 -1 -1 -1 -1
  - Code 2: -1 +1 +1 -1 +1 +1 +1 -1 -1 -1 +1 -1
  - ...
  - Code 11: -1+1 -1 +1 +1 -1 +1 +1 +1 -1 -1 -1
- Augmented Barker codes form orthogonal set

8

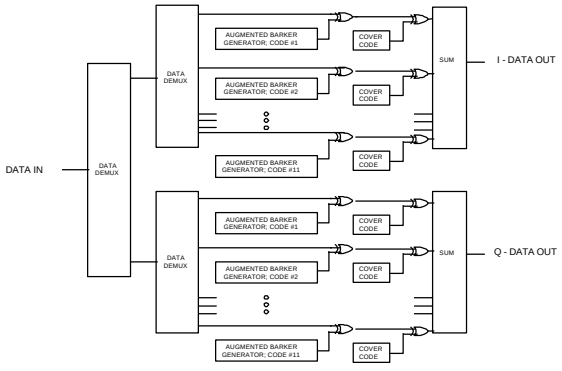
Stacked carrier principle

- Use each member of orthogonal code set to spread spectrum modulate individual data bits
- Add spread spectrum signals
- Transmit composite signal

9

Transmitter block diagram

- New high data rate system packet (except MPDU) or present IEEE 802.11 same as present systems.
- Transmitter block diagram for new high data rate system MPDU is illustrated below



10

Increased data rate method

- Transmitted data rate increases as number of orthogonal codes used increases (one data bit per code)
- Implementations can use 1 to 11 Augmented Barker Codes
- Individual data bits can be recovered due to the orthogonal nature of the spreading code set
- Cover Code has same clock as Augmented Barker Code
- Cover Code is 4095 bits long

11

Data rates

- Chip rate: 11 Mcps
- Processing gain:
  - IEEE 802.11 Mode: 11
  - Proposed new method:
    - All except frame body and CRC32: 11
    - Frame body and CRC32: 12
- Data rates:
  - IEEE 802.11 Mode: 1 Mbps (BPSK), 2 Mbps (QPSK)
  - Proposed new method: 1.83, 3.67, up to 20.16 Mbps in increments of 1.83 Mbps

12

Variable data rate method

- Proposed new method
  - System can use 1 code, 2 codes, … , 11 codes
  - Chip rate (Mcps) - 11
  - PG (augmented Barker code) - 12
  - Data rate (Mbps, BPSK modulation, per code) - 11/12
  - Data rate (Mbps , QPSK modulation , per code) - 11/6
  - Min data rate (Mbps , QPSK modulation , 1 code - 11/6
  - Max data rate (Mbps , QPSK modulation , 11 codes - 20 1/6
- IEEE 802.11 compatible method
  - Same as BPSK, QPSK modulation using one code. Code is Barker code, data rate is 1 and 2 Mbps and PG = 11

13

RF signal bandwidth

- Chip rate is constant and identical to the present IEEE 802.11 standard (11 Mcps).
- RF bandwidth requirements remain identical to present IEEE 802.11 standard based systems

14

RF and despread signal constellation

- RF signal constellation (number of points)
  - 1 code (11/6 Mbps) - 4
  - 2 codes (11/3 Mbps) - 9
  - …
  - 11 codes (20 1/6 Mbps) - 144
- Outer constellation points are low probability; RF can be in soft compression
- Despread signal constellation always QPSK

15

Coexistence and interoperability

- Proposed high data rate system can fully coexist and interoperate with legacy systems, subject to new higher data rates limitations

16

Interoperability scenario

- All systems acquire same spread spectrum SYNC preamble
- All systems detect the same SFD field
- All systems demodulate the same SIGNAL field - this field indicates the data format of the MPDU field. It can indicate:
  - IEEE802.11 (1 or 2 Mbps)
  - Proposed new data rate (one of 11 data rates)
- All systems demodulate the same SERVICE field
- All systems demodulate the same LENGTH field
- All systems demodulate the same CRC16 field
- New systems can then demodulate MPDU at enhanced data rates or at present IEEE 802.11 data rates

17

System complexity

- System complexity increase is small due to utilization of matched filter based technology to implement the following functions:
  - Spread spectrum acquisition
  - Signal despreading
  - BPSK / QPSK demodulation
  - RF tracking (± 25 PPM)
  - Chip tracking (DLL)
  - Diversity processing (selection or Rake with MR combining)
  - Clear channel assessment (CCA) using energy detection at IF and post despreading.

18

System performance

- System performance - multipath
- System performance - RF tracking
- Sensitivity to AGC setting (1)
- Sensitivity to AGC setting (2)

19

System performance - multipath

- Robust performance due to matched filter based technology.
- Multipath resistance for several data rates, 100 byte packet, FER=10e-1, no diversity processing (RAKE)

Data rate (Mbps)	Signal to multipath ratio (dB)
1.83	1.98
3.67	5.2
5.5	7.04
7.33	8.26
9.17	9.25
11	10.1
12.83	10.76

20

System performance - RF tracking

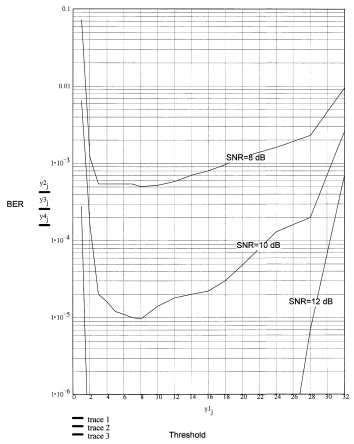
- Digital Costas loop removes frequency offsets of ± 25 PPM.
- SNR (dB) required for several data rates to achieve FER=10e-1 for 100 byte packet. Frequency offsets of 0 and 125 KHz are considered.

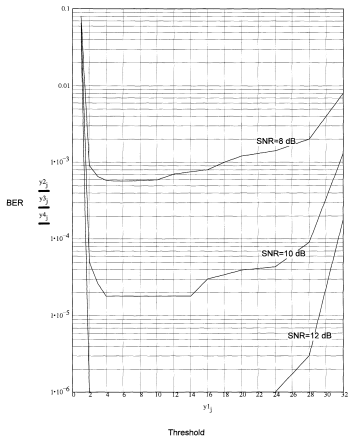
Data rate (Mbps)	Δf=0	Δf=125
1.83	9.4	9.5
3.67	10.2	10.3
5.5	10.4	10.5
7.33	10.5	12.1
9.17	11.4	16
11	11.5	17.5
12.83	12	18.5

21

Sensitivity to AGC setting (1)

- BER vs AGC setting for 8, 10, 12 dB. Data rate of 1.83 Mbps at a frequency offset of 0 KHz (left) and 80 KHz (right).

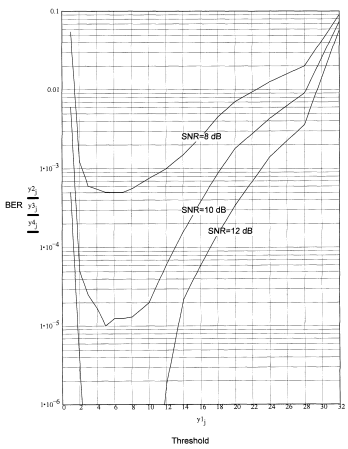


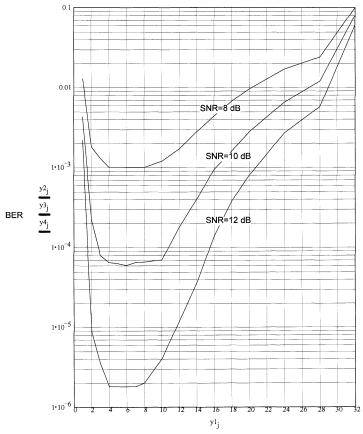


22

Sensitivity to AGC setting (2)

- BER vs AGC setting for 8, 10, 12 dB. Data rate of 12.83 Mbps at a frequency offset of 0 KHz (left) and 80 KHz (right).





23

Conclusions

- Proposed system outlines a flexible signal structure that can be efficiently processed by high performance matched filter based architectures.
- Interoperable with existing systems and capable of trading off cost, power consumption and data rate (11 rates, 1.83 to 20 Mbps plus present 1 and 2 Mbps) while maintaining full interoperability.
- A full range of existing systems, from smallest (and most restricted in power consumption) to largest can communicate using new IEEE Wireless LAN protocol.
- Matched filter based operation can take advantage of multipath to enhance system performance at little or no additional hardware complexity.
- Direct sequence spread spectrum signal structure complies with FCC ISM band definition.

24