Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [HIPERPAN: a COFDM Scheme for IEEE's High Rate WPAN]
Date Submitted: [r6 October 2000]

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Re: [TG3 PHY layer submission]

Abstract: [This contribution is a proposal for a high rate WPAN (up to 43 Mbit/s) operating in the 5GHz U-NII bands. The system uses Coded Orthogonal Frequency Division Multiplex modulation and is compatible with some PHY modes of 802.11a / HIPERLAN/2 standards while offering simplifications that allow a lower complexity, low cost receiver. Note that this proposal is a merging of Motorola and Radiata former contributions.]

Purpose: [Response to WPAN-TG3 Call for Proposals]

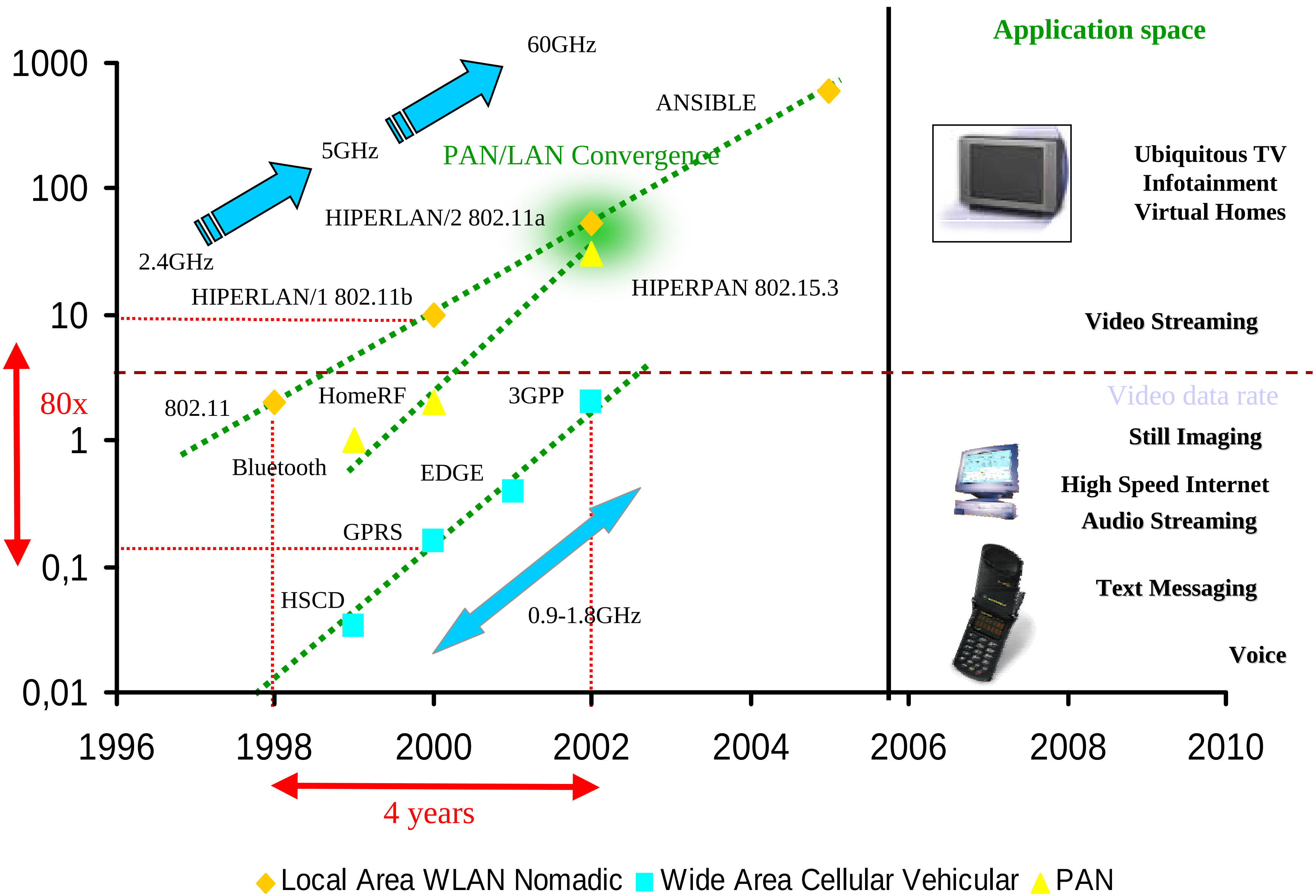
HiPerPAN: a COFDM Scheme for IEEE's High Rate WPAN
A globally harmonized proposal

October 2000

MOTOROLA

Radiata

Convergence scenario: an opportunity!



Motivation for this merged proposal:

① from coexistence to compatibility: grant interoperability with 5GHz worldwide harmonized WLAN standards: IEEE802.11a, ETSI BRAN HIPERLAN/2, ARIB MMAC HiSWAN by providing *a common signal format for resource allocation*

② personal means worldwide operation: provide access to 5GHz band as spectrum opportunity for WPAN: regulatory issue for accessing this license exempt band in Europe, grants 12 channels of 20MHz in the US, 19 channels in Europe, 4 channels in Japan; elsewhere?

Proposal overview

- **5GHz OFDM proposal** merging: this PHY proposal is the result from the merging of the two 5GHz OFDM former proposals (Radiata and Motorola HIPERPAN)
- **MAC pairing**: this PHY proposal is to be paired with the Motorola (Walt Davis)/ShareWave joined enhanced MAC proposal
- Two operating modes are provided:
  - coexistence: requires Dynamic Frequency Selection (DFS) not to disturb WLANs and mandatory for operating in Europe (CEPT). Three different PHY modes defined for payload. Transmit Power Control (TPC) is not required.
  - compatibility: requires additional signalling and the associated PHY mode (BPSK + rate 1/2 bit interleaved convolutional code). QPSK 1/2 is also used for payload compatibility.
- Hooks for compatibility with IEEE802.11a and HIPERLAN/2 are provided at the PHY level, but *will require* MAC enhancements

Worldwide operation at 5 GHz is achieved through harmonization of signalling fields and frame formats

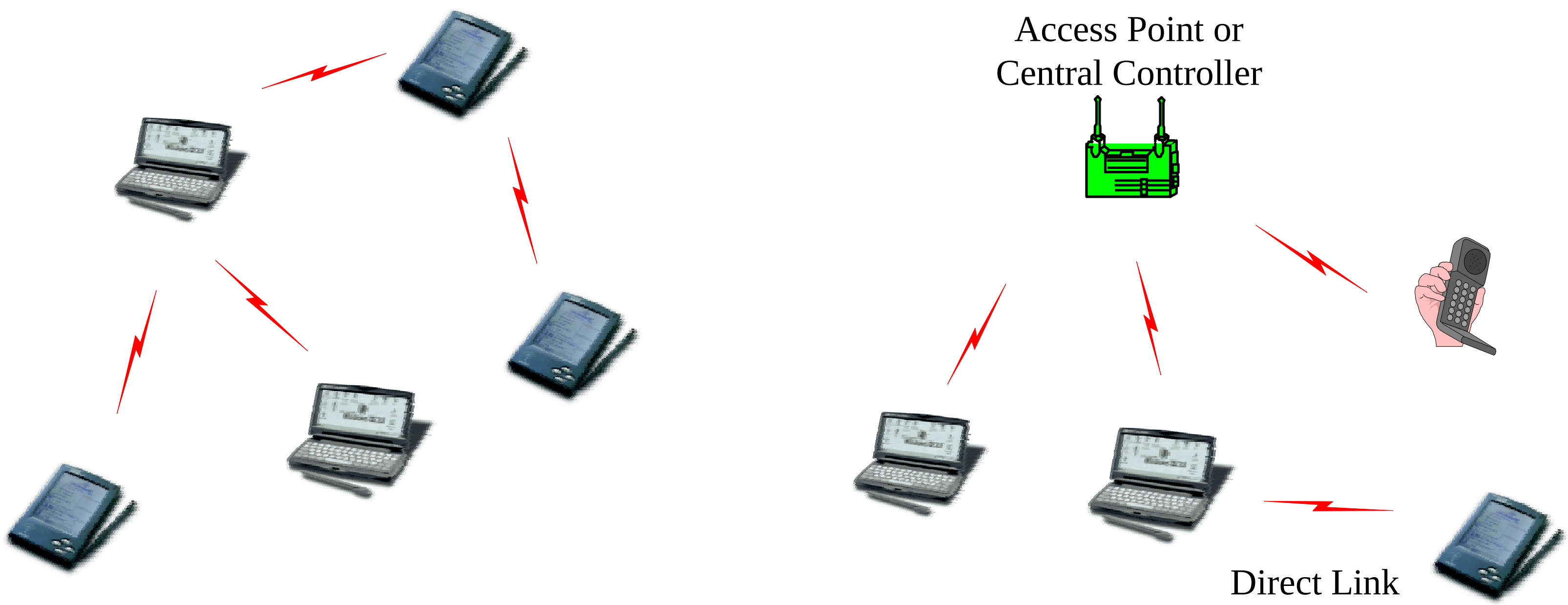
Rationale

- 2.4 GHz spectrum supports multiple communication standards and has many sources of interference that prohibit robust operation
- The spectrum is cleaner at 5 GHz – this proposal keeps it clean by its PHY-level compatibility with existing 5GHz communication standards, including 802.11a and HiPeRLAN/2

Illustration of the different operation modes

Adhoc network: WPAN only or 802.11a

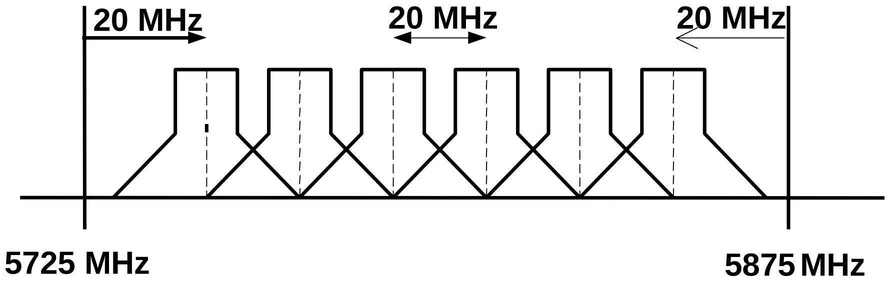
Compatibility mode with HIPERLAN/2



- **Implementation of IEEE802.11a and HIPERLAN/2 signaling fields provide a way to embed WPAN transmissions in the 5GHz OFDM WLANs frame structure**
  - **through PLCP frame format of IEEE802.11a**
  - **through Direct Link resource allocation requests in HIPERLAN/2**
- **The WPAN payload is conveyed using dedicated WPAN constellations**

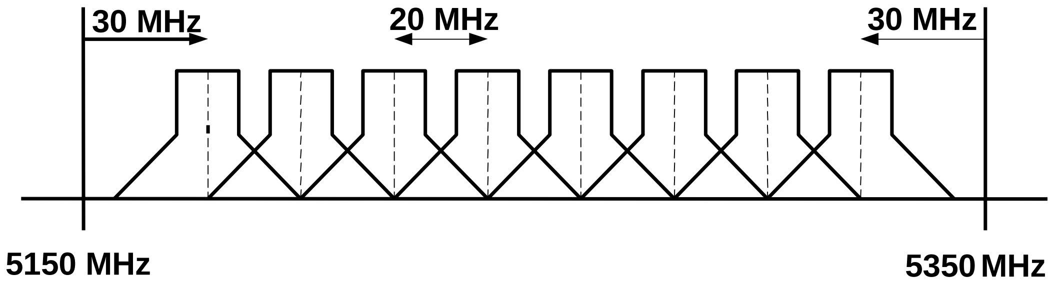
PMD - Worldwide 5 GHz Spectrum

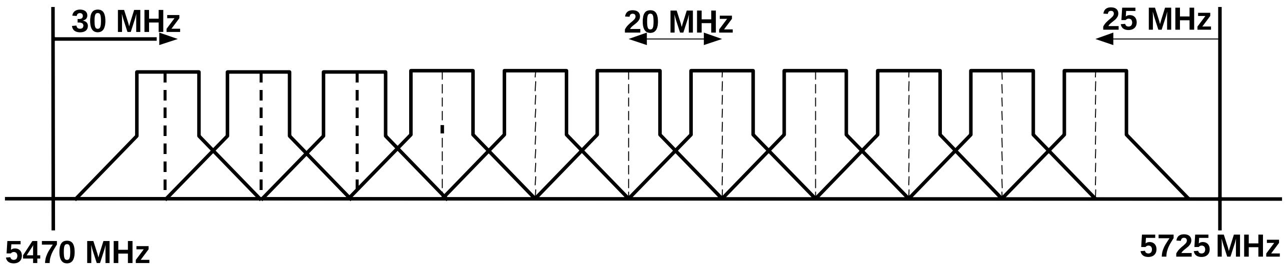
- Spectrum available worldwide in 5.8 GHz ISM band (5725-5875 MHz)
- Regional constraints apply e.g.
  - Europe allows whole band with 25mW EIRP power limit and no channelization restrictions
  - Australia allows whole band with 1W EIRP power limit and no channelization restrictions
  - 6 channels are possible (see below)



PMD – HiPeRLAN channels

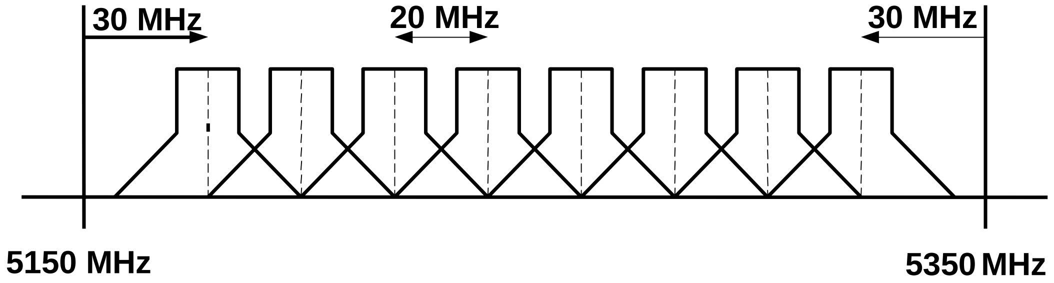
- In Europe, HiPeRPAN’s compatibility modes may additionally open the way for eventual use of the 19 channels in the HiPeRLAN bands (5150-5350 MHz & 5470-5725 GHz)

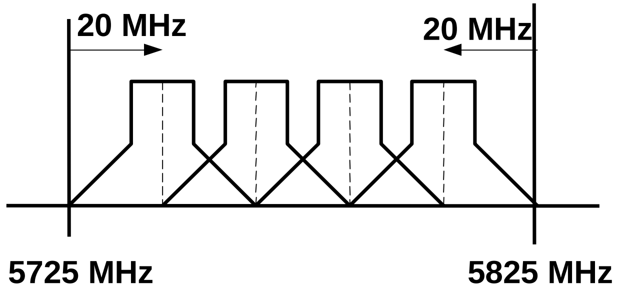




PMD – Channels in North America

• Use same channels as IEEE 802.11a: 12 channels in the non-contiguous 5 GHz Unlicensed National Information Infrastructure bands



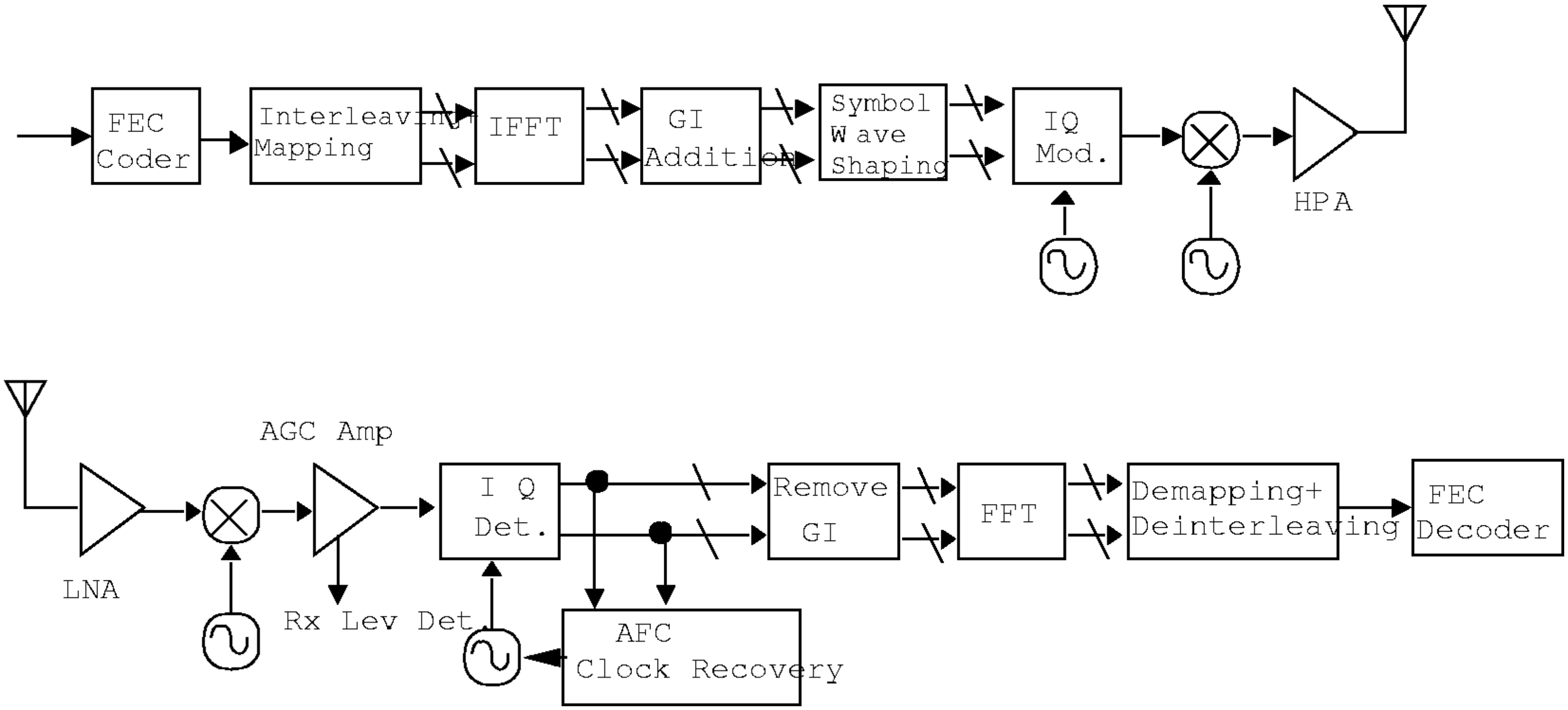


PMD - OFDM Parameters

Propose use of a coexistence/compatibility COFDM system with 52 carriers in a 20 MHz channel with 400ns guard time for multipath signals.

Parameter	*Value* Signalling fields (compatibility)	Direct Link (payload)
Sampling rate fs=1/T	20 MHz	
Useful symbol part duration	64*T 3.2 us	
Cyclic prefix duration	16*T 0.8us	8*T 0.4us
Symbol interval	80*T 4.0us	72*T 3.6us
Number of data sub-carriers	48	52
Number of pilot sub-carriers	4	0
Total number of sub-carriers	52	52
Sub-carrier spacing	0.3125 MHz	
Spacing between the two outmost sub-carriers	16.25 MHz	

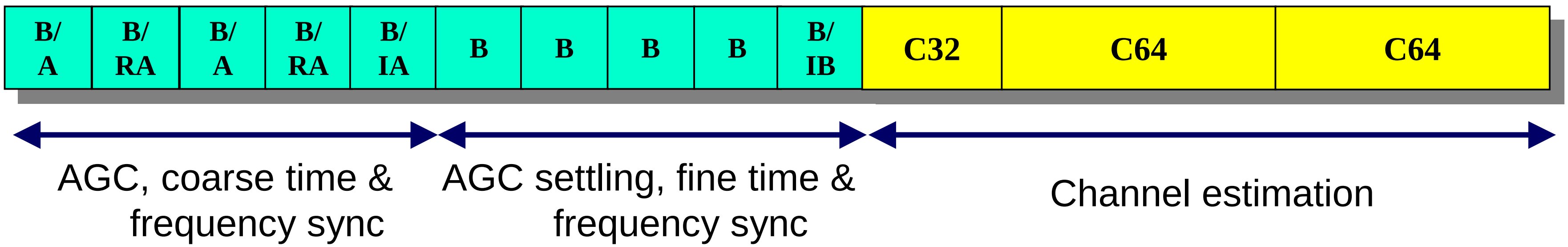
OFDM PHY overview



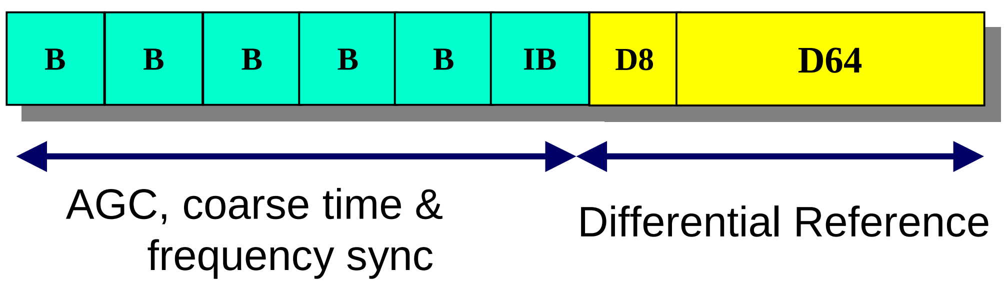
PLCP - Preamble & sync

- Include support for 2 preamble formats:
  - IEEE802.11a / HiPeRLAN/2 for compatibility
  - WPAN only: 802.15.3

- **Compatibility: 802.11a PLCP / HiPeRLAN/2 BCH preamble (16μs)**



- **WPAN only: 802.15.3 preamble proposal (8.4μs)**



Note that differential modulation greatly simplifies synchronization, avoids equalization and reduces preamble length

PMD - PHY Rates

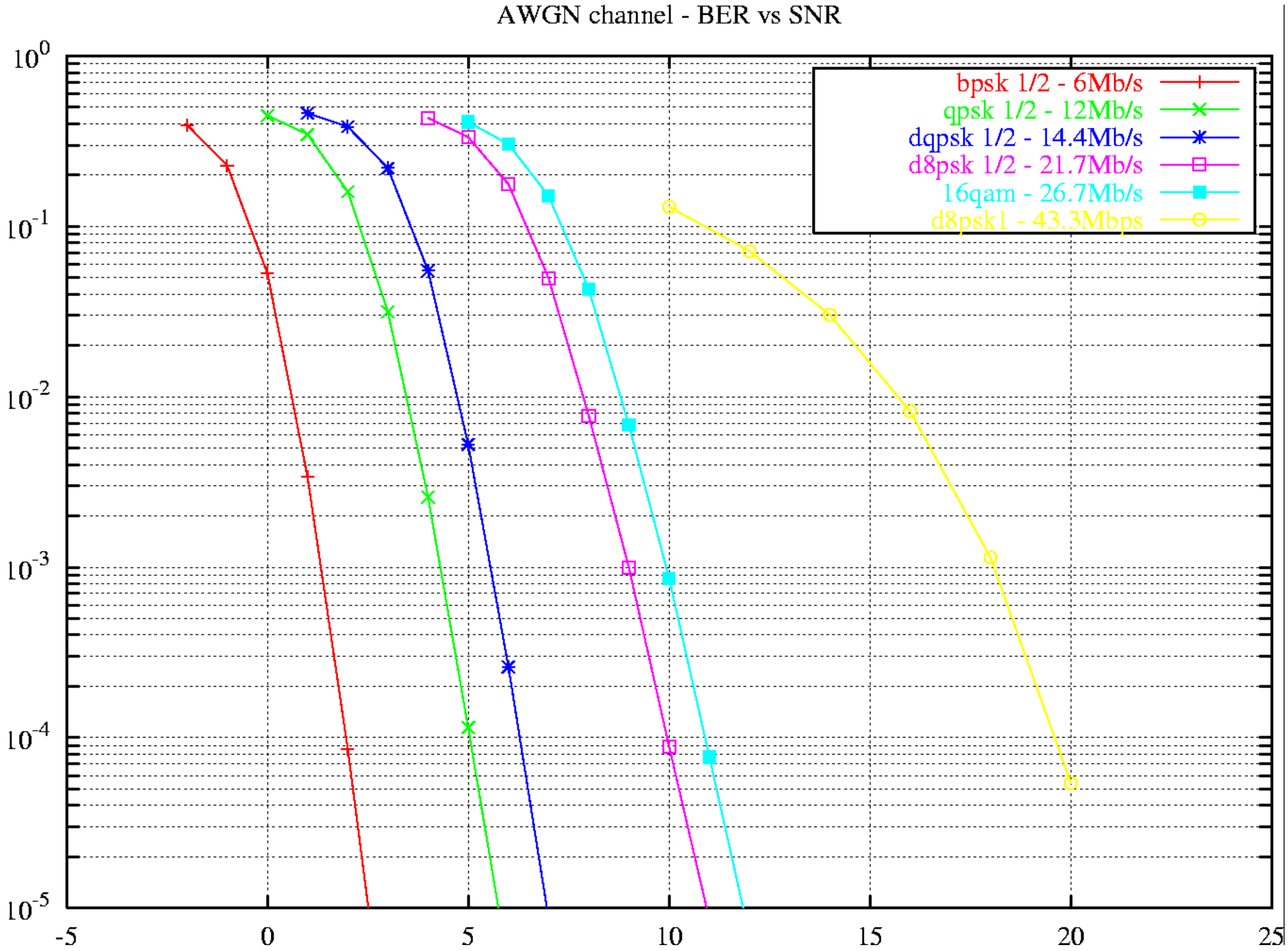
- The proposal provides 6, 12, 14, 21, 26 & 43 Mbit/s using bit interleaved convolutional coded BPSK, QPSK, DQPSK, D8PSK and 16-QAM, & uncoded D8PSK modulations. Data is scrambled and a length 52 or 48 interleaving is used.
- BPSK, QPSK and 16-QAM modes provide compatibility with standardized 5 GHz OFDM systems.

Data Rate Mbit/s	Modulation/ Code	Coding rate	coded bits per subcarrier	Eb/N0 BER 10^-5	C/N BER 10^-5	Range m (Free Space)	Range m (ITU 0 Floor)	Range m (ITU 1 Floor) [1]	Number of pilots
6.0	BPSK (2,1,7)	1/2	1	6	3.0	298	39	12	4
12.0	QPSK (2,1,7)	1/2	2	6	6.0	211	32	10	4
14.4	DQPSK (2,1,7)	1/2	2	7.3	7.3	181	29	9	0
21.7	D8PSK(2,1,7)	1/2	3	10.7	12.5	100	20	6	0
26.7	16-QAM(2,1,7)	1/2	4	12.0	15.0	75	16	5	4
43.3	D8PSK uncoded	1	3	17.3	22.1	33	10	3	0

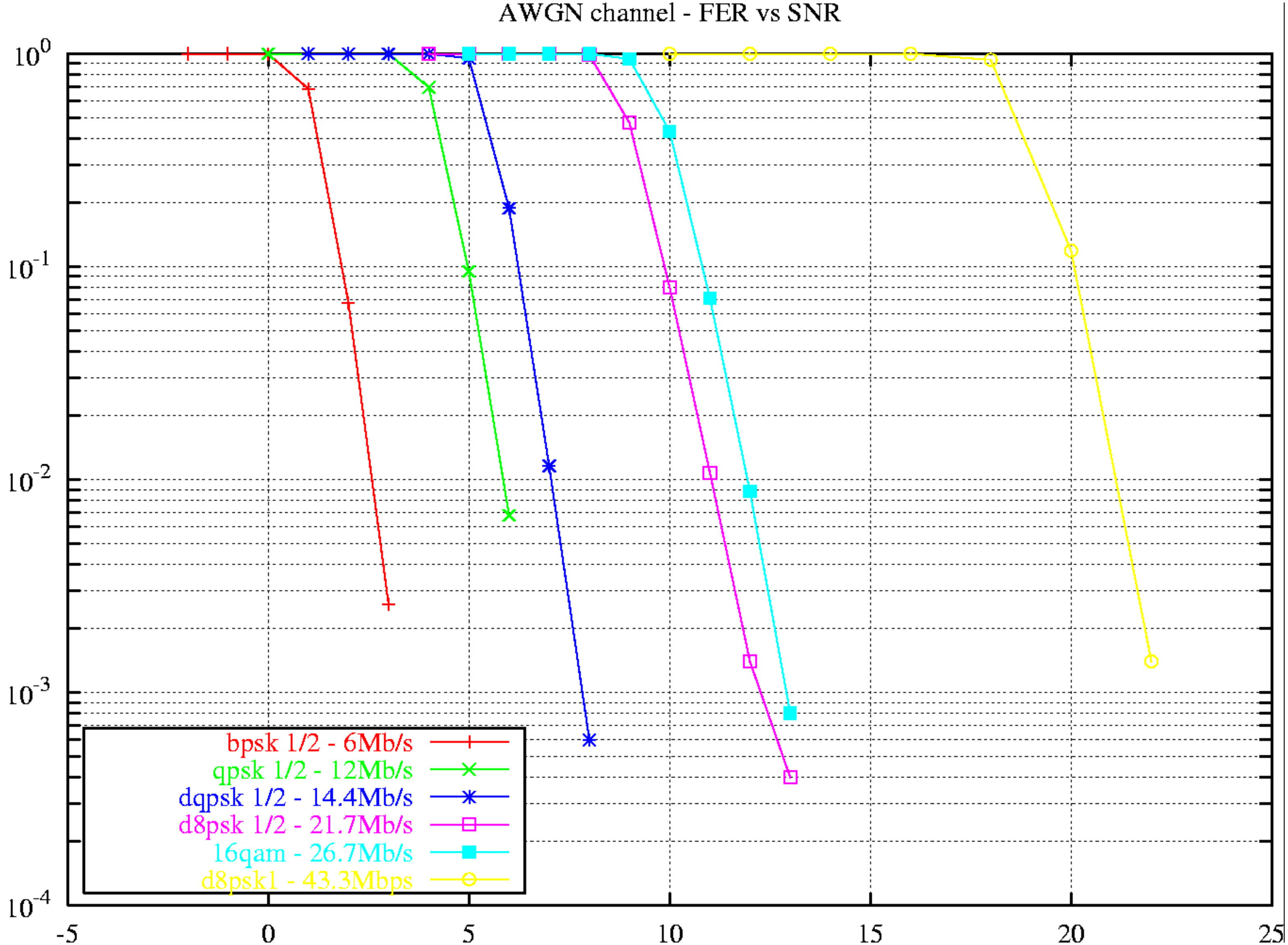
- AWGN channel, range for 1mW Tx power, 0 dBi Tx antenna gain, 0 dBi Rx antenna gain, 6 dB Rx NF and path loss based on ITU P.1238

[1] floor attenuation = 16dB

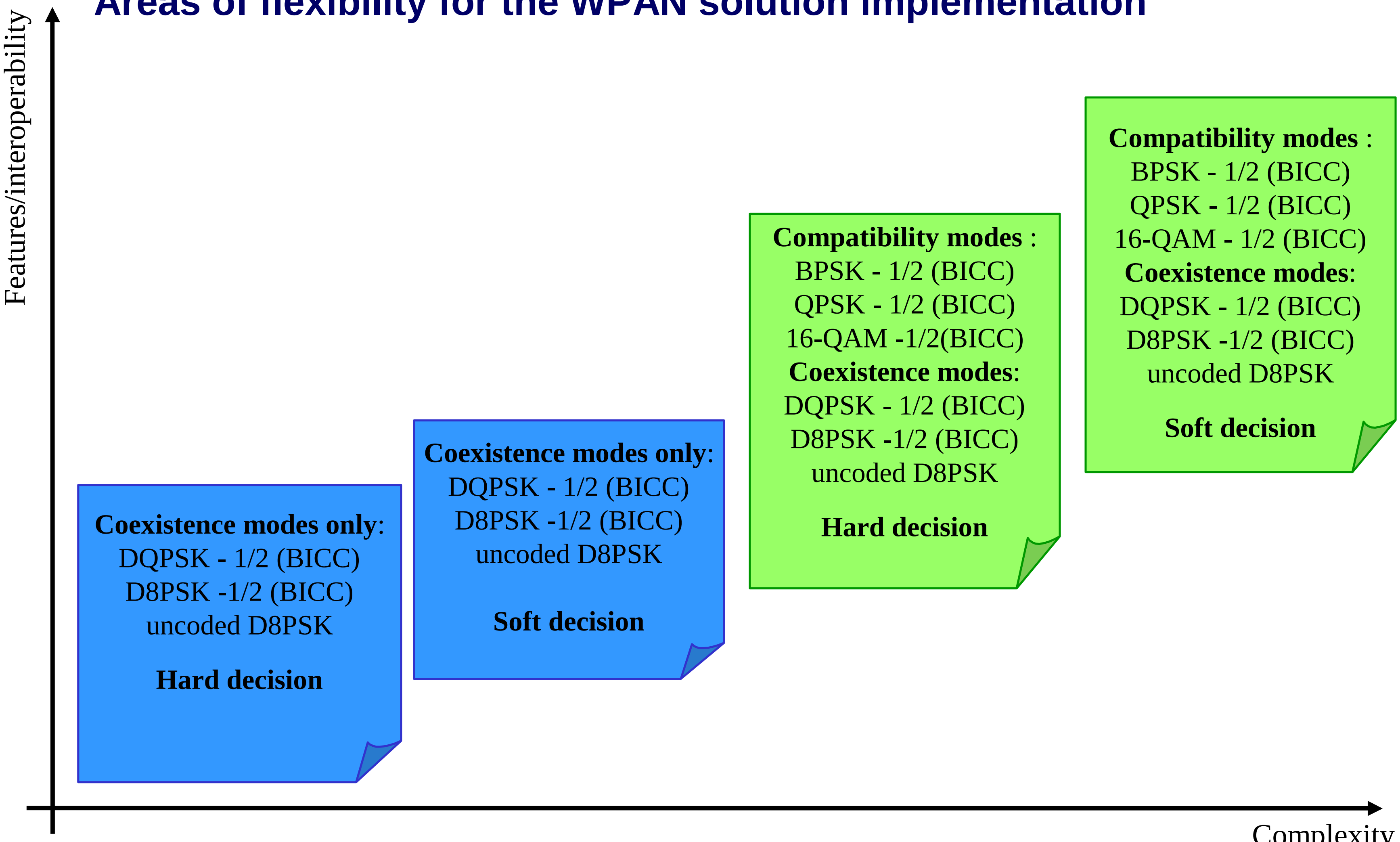
BER Performance (504 bytes packets, 5000 packets TX)



FER Performance (504 bytes packets, 5000 packets TX)



Areas of flexibility for the WPAN solution implementation

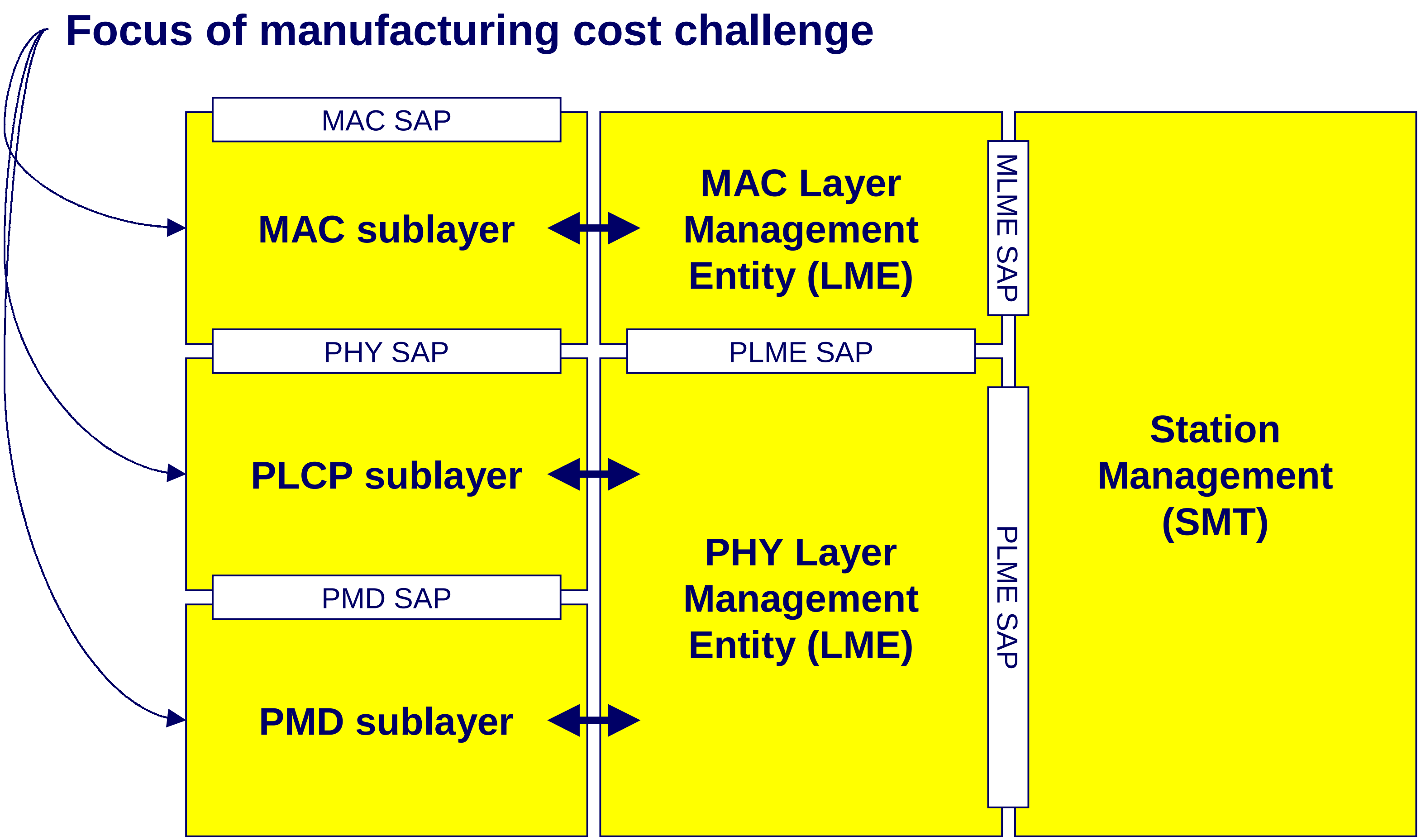


General solution criteria

26 October 2000

2.1 Unit Manufacturing Cost

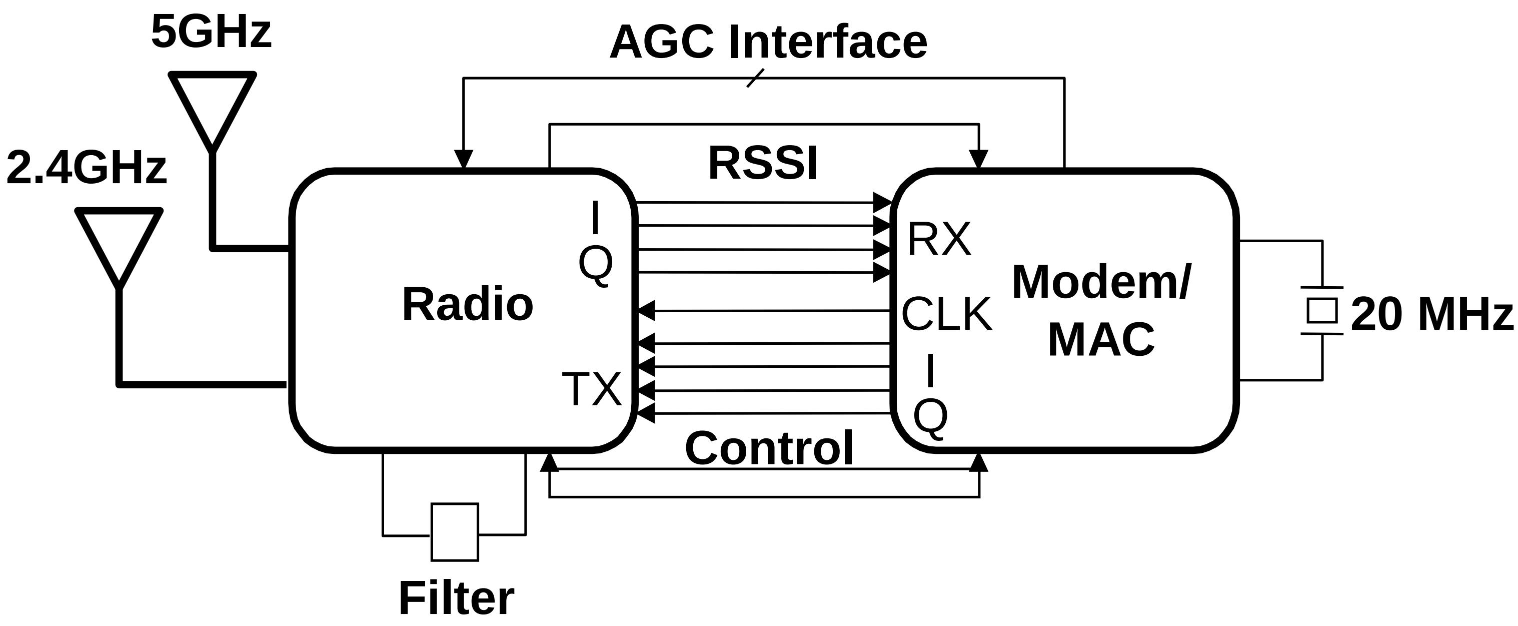
Suggest node structure as shown below - an elaboration of Figure 1 of the TG3 Criteria Definitions document



2.1 Unit Manufacturing Cost

NIC consists of 2 chips with minimal passive and no extra active components

802.15.1 compatibility by:
- •Dual front-end 2.4 GHz and 5 GHz (IF section, control and AGC reused)
- •Modem with 802.15.1 and HiPeRPAN baseband sections
- •MAC provides 802.15.1 mode



2.1 Unit Manufacturing Cost

All active components can be implemented in CMOS - initially a modem/MAC chip and an RF chip, and eventually a single chip

- Modem is order 160k gates (scaling from our implementations of 802.11a and HiPeRLAN/2 systems):

⇨ Digital baseband is more than 2 times smaller than 802.11a

- Add Dual (I/Q) 8-bit ADCs and DACs
- MAC is order 60k gates plus memory
- A 0dBm, 6dB NF 5 GHz dual conversion transceiver including VCOs and filters is now possible in 0.18um CMOS in a chip area of less than 18mm^2 with good yield
- CMOS cost curves will guarantee the continued price reductions needed to achieve target consumer cost levels

⇨ Cost factor reduction factor of >2 expected for HiPeRPAN compared to IEEE 802.11a due to simplified baseband and low Tx power

2.2 Signal Robustness

- **2.2.2. Interference and Susceptibility**
  - COFDM is relatively tolerant of interference. Cochannel interference is determined by the C/N of the modulation employed on each carrier. Adjacent channel is largely determined by specifics of the implementation. Bluetooth spec is almost equivalent to IEEE802.11a. Meeting these will grant the same interference and susceptibility. 35dB (excluding co- and adjacent channel) rejection is readily achievable with IF saw filters.
- **2.2.3. Intermodulation Resistance**
  - LNA IP3 of –17 dBm is achieved for CMOS RF chip.
- **2.2.4. Jamming Resistance**
  - 802.11a cannot be considered as a jammer since compatibility is achieved (common BPSK/QPSK modes). 802.15.1 and 802.11b cannot interfere since they are in the 2.4 GHz band. 5 GHz is immune to microwave oven spurious emission.
- **2.2.5. Multiple Access**
  - The existence of multiple channels allows multiple systems to coexist without interference, one in each channel. The system filtering, proposed to be the same as 802.11a, ensures low non-interfering out-of-channel emissions
  - MAC must have DFS
- **2.2.6. Coexistence**
  - The only potentially interfering system is 802.11a - use of DFS will ensure coexistence
  - Proposal allows WPAN stations to interpret 802.11a signalling and act accordingly.

2.3 Interoperability

The proposed system is fully interoperable with 802.15.1 through the addition of a compatibility mode

- 802.15.1 is at 2.4 GHz
- This high rate proposal uses a quadrature radio transceiver with a front-end in the 5 GHz band
- An 802.15.1 compatibility mode is achieved with an additional 2.4GHz front-end and down converter and then reusing the remainder of the radio chain (IF section) and second mixer
- the 802.15.1 signal is decoded in a separate baseband module

③ The additional 2,4 GHz front-end modules in the RF are small and the baseband demodulator chain for 802.15.1 is tiny

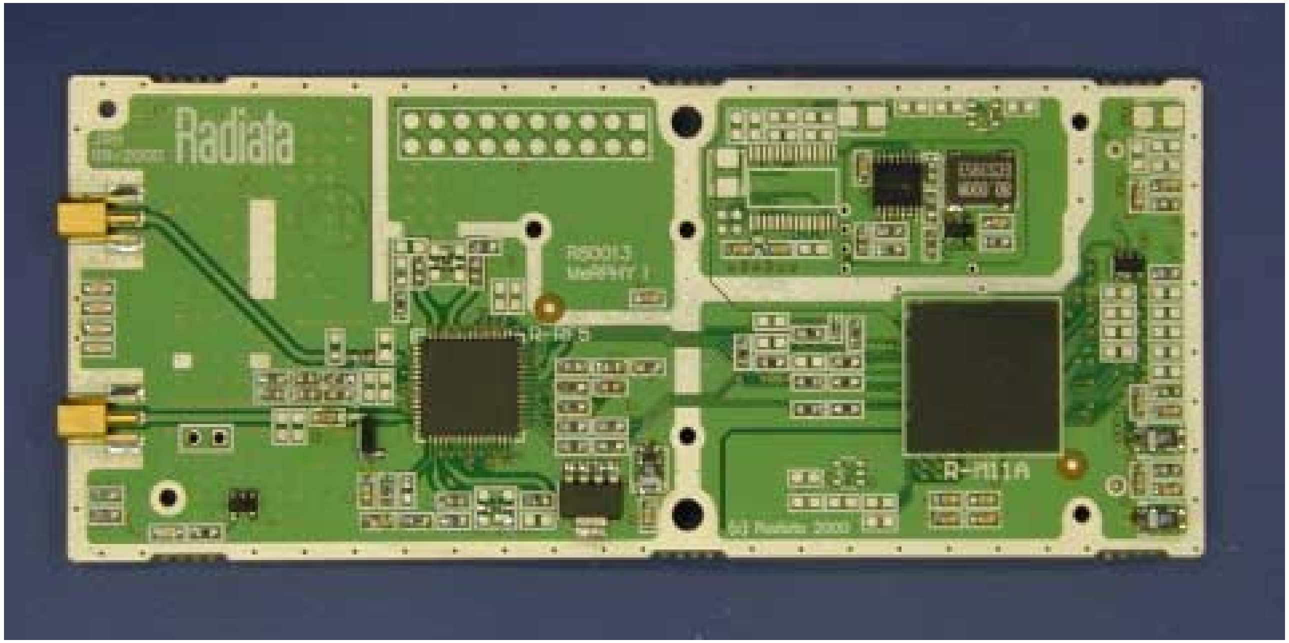
2.4 Technical Feasibility

Eminently feasible

- **2.4.1. Manufactureability**
  - The picture displayed next slide shows a complete PHY for the IEEE 802.11a WLAN standard including a single chip modem and single chip 5 GHz radio plus an LNA, PA, tx/rx switch and diversity switch. The LNA, PA and diversity switch are not needed for a WPAN, which requires only passive components and an oscillator and tx/rx switch plus the modem and radio chips. This implementation is in a PCMCIA Type II format and uses one board side only of a six layer board. The layout is -very- sparse and could be shrunk to compact flash size. This implementation demonstrates the manufacturability of the technology.
- **2.4.2. Time to Market**
  - Modem and MAC chips of greater complexity have been demonstrated
  - Prototype 5 GHz RF CMOS transceivers have been demonstrated and production versions are in development with demonstrations expected before the end of 2000
- **2.4.3. Regulatory Impact**
  - TRUE (U-NII rules) (for Europe, see CEPT/ERC/REC 70-03E)
- **2.4.4. Maturity of Solution**
  - COFDM systems of this type have been built and run by several groups and companies around the world. Two companies have announced chipset products for IEEE802.11a.
  - COFDM systems already are available on the market place and operating: ADSL (6Mbps), Digital Audio Broadcasting (1.5Mbps), Digital Video Broadcasting (36Mbps)

2.4.4 Technical Feasibility - Maturity of Solution

Complete COFDM (802.11a) PHY layer on one side of a PCMCIA card - sparse layout can compress to CF format single side.



2.5 Scalability

COFDM is very scalable. The parameters and functionality for this proposal are optimised for a global cost/data rate/complexity/power tradeoff given the relatively less demanding PAN compared to a LAN.

- **Power consumption**
  - Can be controlled by variable transmit power
- **Data Rate**
  - Data rate in this proposal can be scaled by increasing the clock rate and, consequently, bandwidth and power consumption (there is effectively an upper limit on bits/Hz for a low complexity, low power design)
- **Frequency Band of Operation**
  - Operation in any frequency band is possible - 5 GHz is attractive because of the low level of interfering signals
- **Cost**
  - The proposal is optimized for cost - reductions will be incremental and process and volume driven
- **Function**
  - The proposal functionality is aimed at achieving a balanced cost/compatibility tradeoff. Skipping compatibility modes will decrease the overall system cost.

802.15.3 PHY Criteria Notes

26 October 2000

4.1 Size and Form Factor - New criteria

- (1) Radio functionality/size:
  - Q: How backward compatibility with 802.15.1 spec is achieved, (RF blocks repeated, shared, etc.?)
  - A: This high rate proposal requires a quadrature radio transceiver with a front-end in the 5 GHz band. With a 2.4GHz front-end and down converter the remainder of the radio is used and the 802.15.1 signal decoded at baseband.
  - Q: Transmit power, power amplifier back-off, and efficiency at the transmit power
  - A: Tx power is 0 dBm. For a non-linearised power amplifier, the required backoff is 4-5 dB from the 1 dB compression point of the output PA. This can be improved significantly with even modest linearisation of the output PA. Improvements of at least 2dB might be expected (ie to 3dB backoff) for a linearised PA. The efficiency depends heavily on the implementation. The worst case is a Class A output stage, which for 5 dB backoff would achieve around 8% efficiency.
  - Q: Chip area, process technology
  - A: The chip area for the transceiver, including on-chip analog filters, is estimated to be less than 18 mm^2 in 0.18u CMOS technology. This area estimate is obtained by scaling of an existing implementation of a single chip 5 GHz CMOS transceiver for the 802.11a WLAN standard. It is anticipated that this area will be reduced as the design is refined.

4.1 Size and Form Factor - New criteria (cont.)

- (2) Baseband functionality/size (PHY baseband only):
  - Q: A/D and D/A converter precision, speed
  - A: 8-bit A/D and D/A provide ample quantization noise as well as head room for AGC acquisition. 40 Msample/s quadrature units (baseband I/Q converters) give more than 2x oversampling and result in quite relaxed tx/rx filter specifications. The required ADC accuracy is 6.9 ENOBs for 16dB margin and the strictest constellation.
  - Q: Digital filter lengths for pulse shaping
  - A: raised cosine OFDM symbol shaping requires simple shift and add operations over three samples only
  - Q: Equalizer length (i.e., number of coefficients)
  - A: Not applicable for OFDM
  - Q: Decoder complexity (e.g. type of decoder like convolutional or block)
  - A: A Viterbi decoder is required for decoding the standard (2,1,7) code; this is a 64-state decoder and could be hard decision, which, together with the fact that code puncturing is not used, yields a decoder about 40% of the complexity of that required for a full WLAN implementation. This yields an approx complexity 25k gates.

4.1 Size and Form Factor - New criteria (cont.)

- (2) Baseband functionality/size (cont.)
  - Q: CMOS chip area, gate count and process technology
  - A: The chip area for the modem including A/Ds and D/As is estimated to be less than 14 mm^2 in 0.18u CMOS technology. Gate count is approximately 150k gates (approx 90k for WPAN mode plus additional 60k gates for WLAN compatibility modes). This estimate is obtained by scaling from existing chip implementations of the IEEE 802.11a PHY

- (3) Total number of chips and external components for the overall PHY solution
  - Two chips are required for a full PHY solution: one modem and one transceiver. Note also that the modem and MAC would be implemented as a single chip from the outset. Additional components are a clock oscillator and passive components only, including VCO loop filters, power supply bypass capacitors and ferrite beads, D/A output biasing resistors, 5 GHz output stage matching circuit, Rx and Tx IF filters (one SAW, one probably passive ladder filter).

4.2 PHY Throughput

Delivered data throughputs (after MAC and PHY overheads are subtracted) are 23.9 Mbit/s (16-QAM) and 38.7 Mbit/s (D8PSK uncoded) based on MAC committee worst case overheads

Data Rate (Mbit/s)	*Modulation/ Code*	*Delivered Data Throughput (Mbit/s)*
6.0	BPSK (2,1,7)	5.4
12.0	QPSK (2,1,7)	10.7
14.4	DQPSK (2,1,7)	12.9
21.7	D8PSK(2,1,7)	19.4
26.7	16-QAM(2,1,7)	23.9
43.3	D8PSK uncoded	38.7

Note: The MAC overhead used here is the worst case scenario determined by the MAC sub-subcommittee in detail in doc.:802.15/EK_MacHdr_and_ProtocolOverhdTbl

4.3 Frequency Band

Spectrum regulation status: where to operate worldwide

Band	range GHz	USA	Europe
I	5.15-5.35	unlicensed	license exempt
II	5.47-5.725	unavailable	license exempt
III	5.725-5.825	unlicensed	unlicensed
IV	5.825-5.875	unavailable?	unlicensed

Bands I and II are reserved to HiPeRLANs in Europe (DFS&TPC mandatory, modulations: GMSK and OFDM)

Remarks:

1) HiPeRPAN operates full rate (43Mbps) in the US in the bands I and III
2) HiPeRPAN will operate full rate (43Mbps) in EU in bands III and IV (25mW restricted - see CEPT/ERC/REC 70-03E Annex 1)
3) for the moment HiPeRPAN is able to operate at reduced rate (12 Mbps) in EU in bands I and II. The goal (and this is under discussion at ETSI), is to have WPAN included in the BRAN standard - that would allow the full rate operation in these two bands as well.

4.4 Number of Simultaneously Operating Full Throughput PANs

Twelve full rate simultaneously operating PANs can operate in one POS in the USA; OR
We can at least tile the world with 26.7 Mbit/s full rate PANs.

- – Co-channel interference limits determine a minimum distance before a channel can be reused
- – Reuse distance depends on the rate of increase of path attenuation with distance
- – For a path loss exponent of 3.1 and hexagonal cells,
  - 10 channels are required for 43.3 Mbit/s D8PSK uncoded mode
  - 6 channels are required for 26.7 Mbit/s 16-QAM rate 1/2 mode

IMPORTANT NOTE: This performance is achieved without impact on other criteria ratings.

4.5 Signal Acquisition Method

The system requires AGC, coarse timing sync and coarse frequency acquisition. It avoids the need for fine lock by the use of only differential modulation

- AGC based on fast RSSI and receiver gain control performed digitally well within the A16 preamble sequence
- coarse timing and frequency acquisition using A16 symbols
- differential phase reference provided by D64 symbol (with its D8 cyclic extension)

4.6 Range

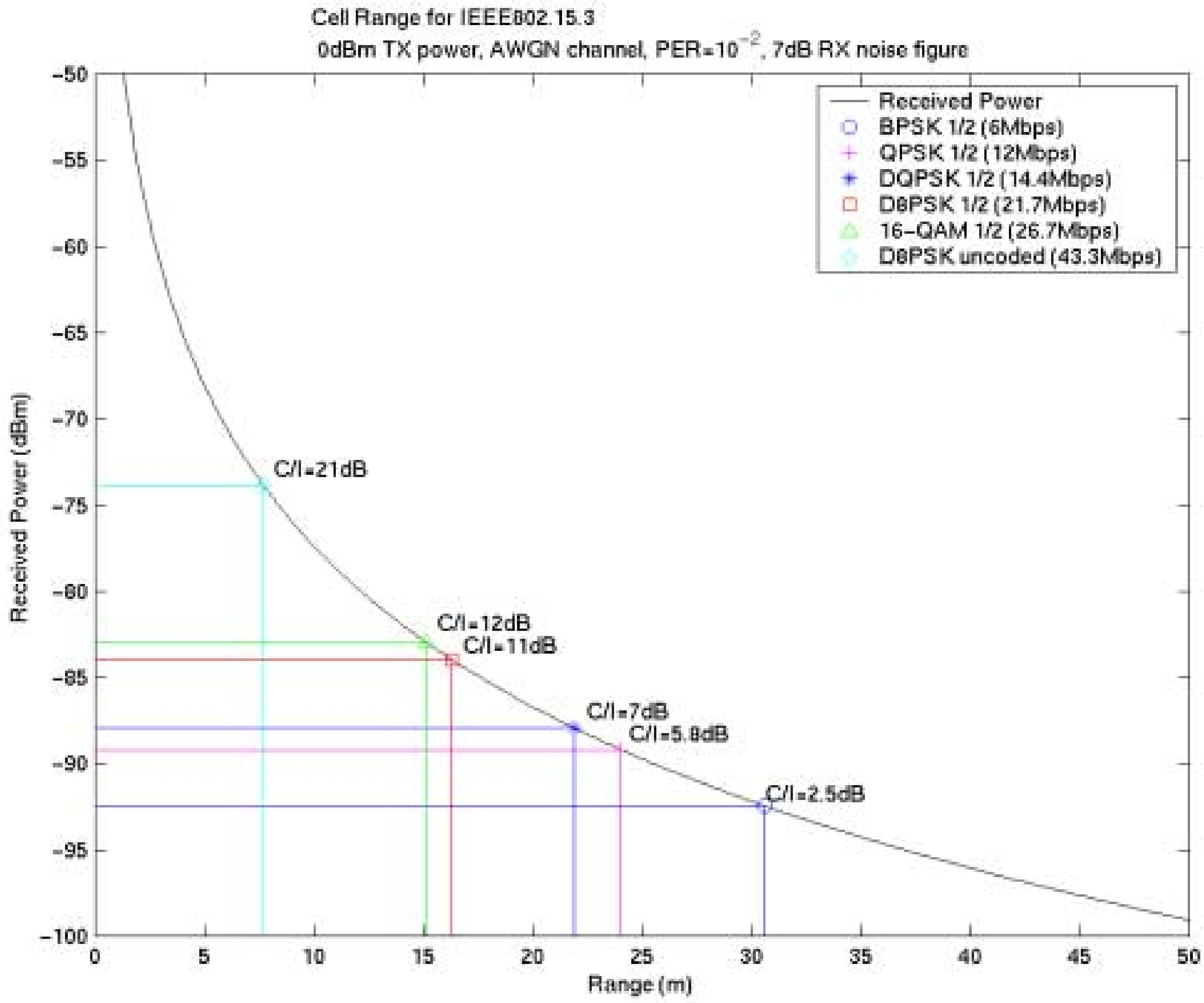
Range for 1mW Tx power, 0 dBi Tx antenna gain, 0 dBi Rx antenna gain, 6 dB Rx NF and path loss based on ITU P.1238 exceeds 10 m for all rates

- Range for 14.4 Mbit/s signal field exceeds 20m
- Range for 26.7 Mbit/s link exceeds 16m
- Range for 43.3 Mbit/s link exceeds 10m
- (see table on slide 13)
  - *ITU-R Recommendation P.1238 (1997) - PROPAGATION DATA AND PREDICTION MODELS FOR THE PLANNING OF INDOOR RADIOCOMMUNICATION SYSTEMS AND RADIO LOCAL AREA NETWORKS IN THE FREQUENCY RANGE 900 MHz TO 100 GHz*
  - The basic model has the following form:

$$L_{total} = 20 \log_{10} f + N \log_{10} d + L_f(n) - 28 \quad \text{dB} \qquad (1)$$

  - where:
  - N : distance power loss coefficient
  - f : frequency (MHz)
  - d : separation distance (m) between the base station and portable
  - L_f : floor penetration loss factor (dB)
  - n : number of floors between base and portable.

4.6 Range and C/I measurements for FER of 10^{-2}



4.7 Sensitivity

Minimum sensitivity is -78 dBm

- The minimum sensitivity for the coded modulation at a BER of 1e-5 (a PER ~1%) is -78 dBm.
- This includes a NF of 7dB and an implementation loss of 1 dB and measurement at the antenna connection point

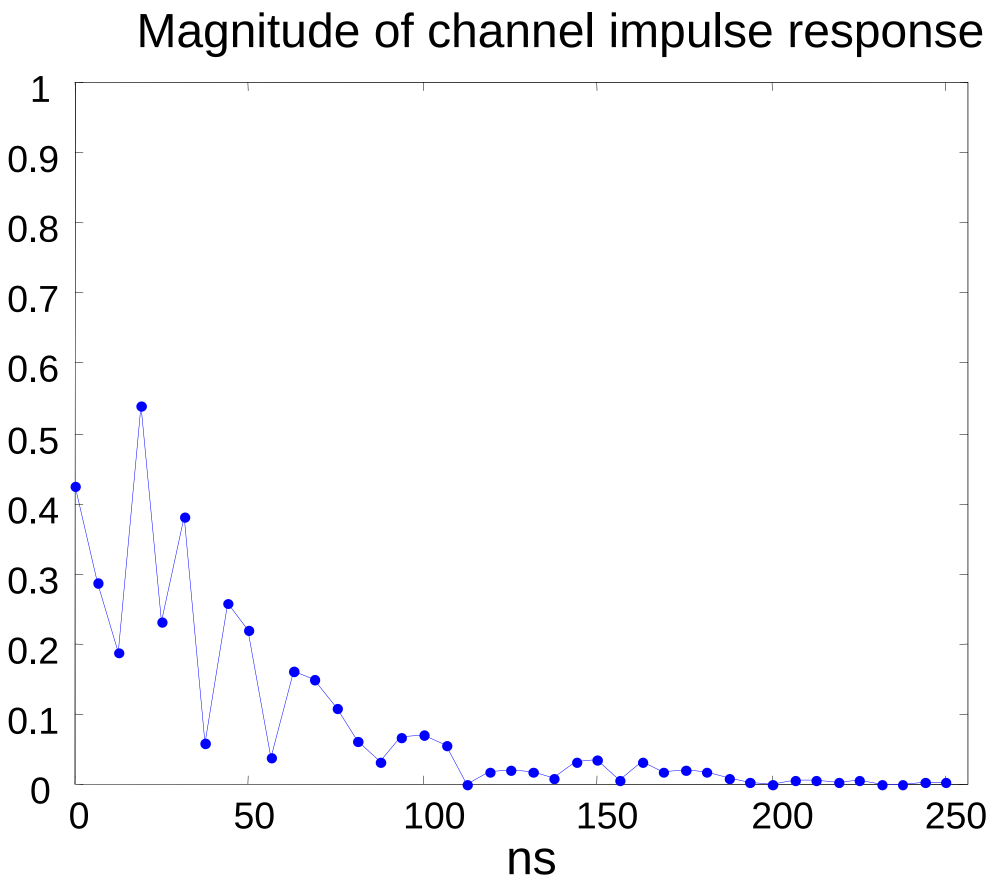
4.8 Multipath Immunity

The delay spread tolerance is excellent for 10ns, 25ns, 40ns and 50ns

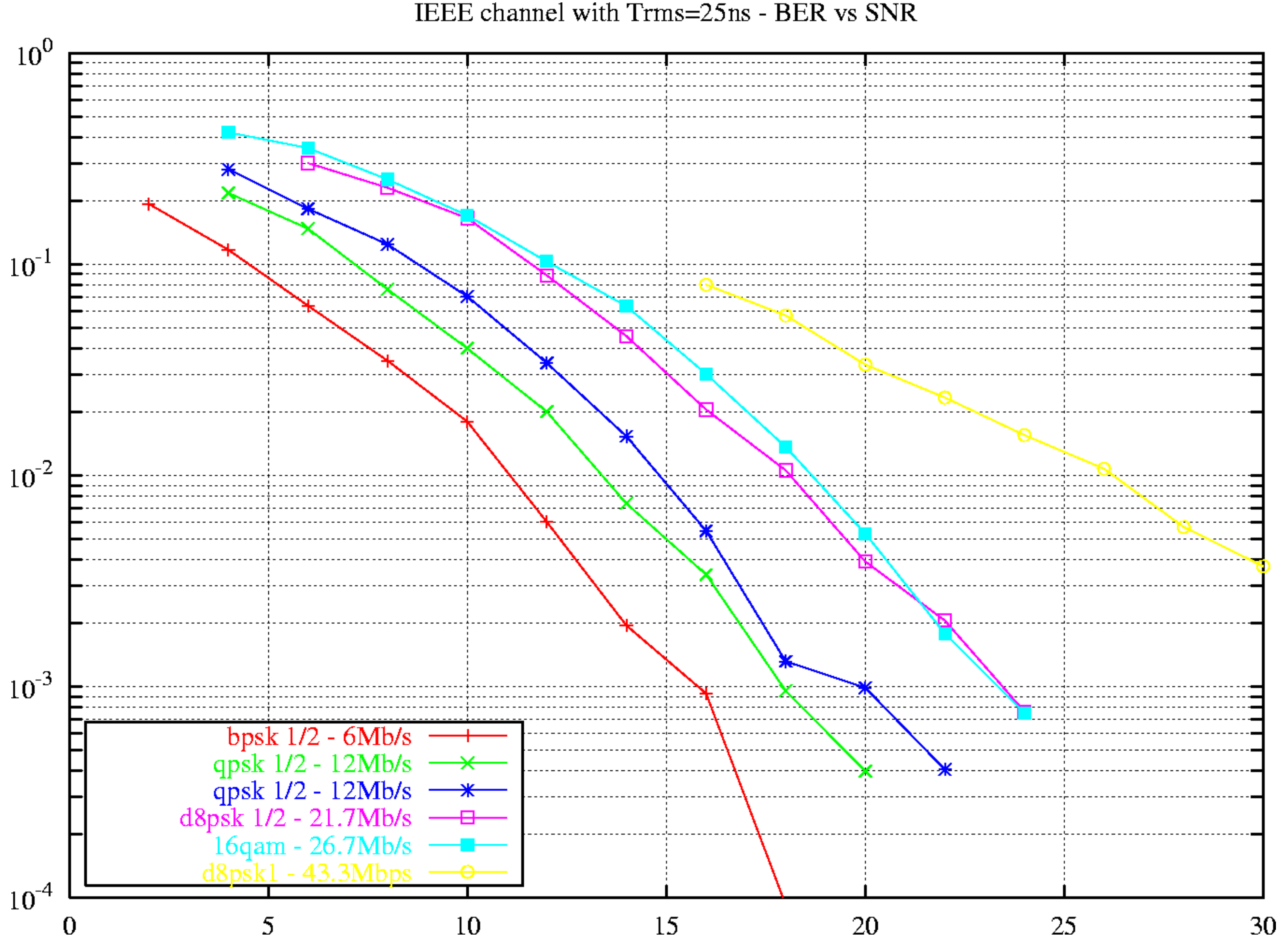
- **4.8.2. Delay Spread Tolerance**
  - Guard time (or cyclic prefix) is of length 400ns ie immunity is granted for multipath up to 400ns before observing intersymbol interference (Inter-carrier interference)
  - This will give at least Trms = 50ns for an exponentially decaying model
  - Results are shown on following slides

4.8 Multipath Immunity

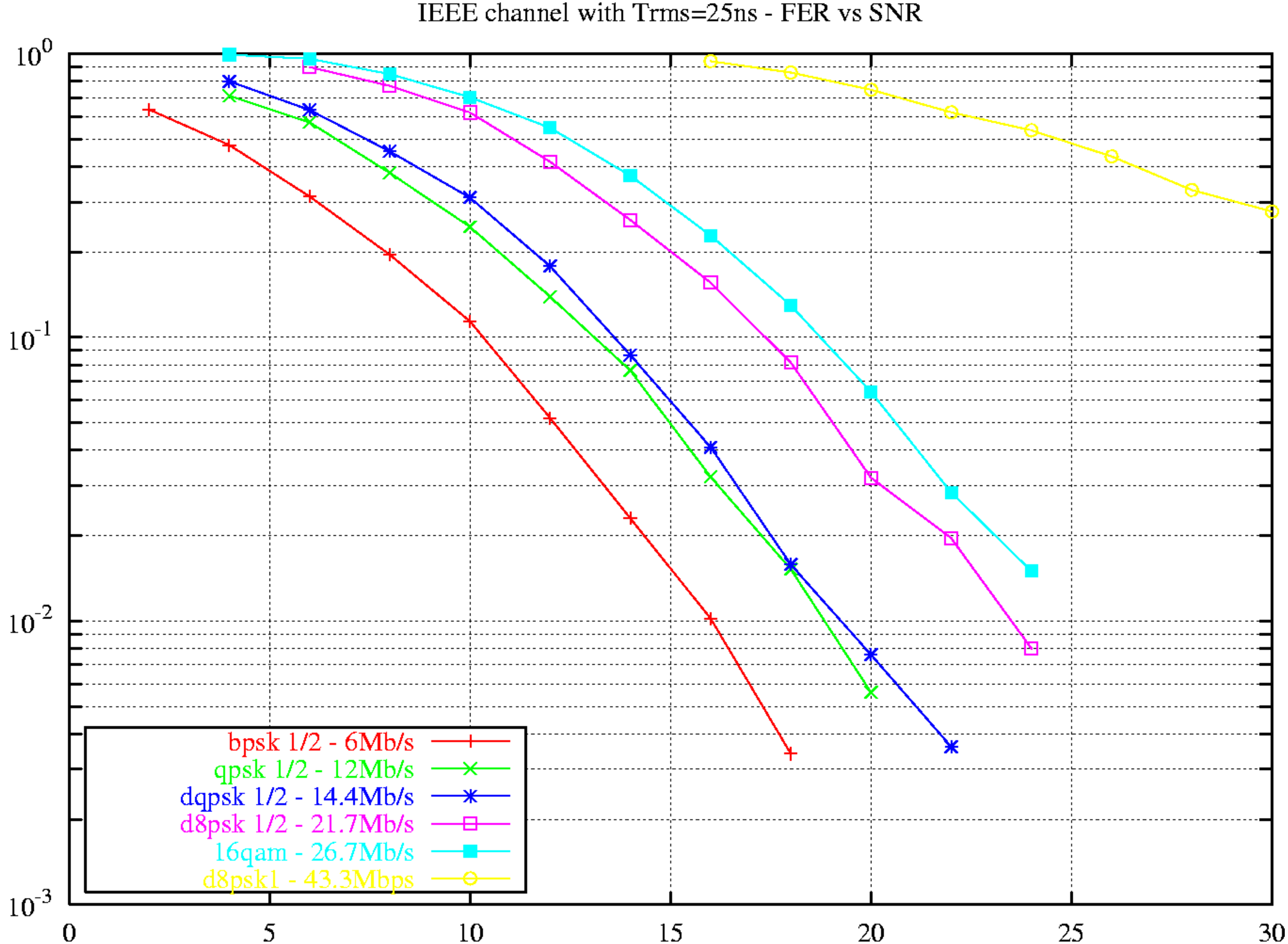
Sample channel with Trms = 25ns generated according to environment exponential model in section 4.8.1



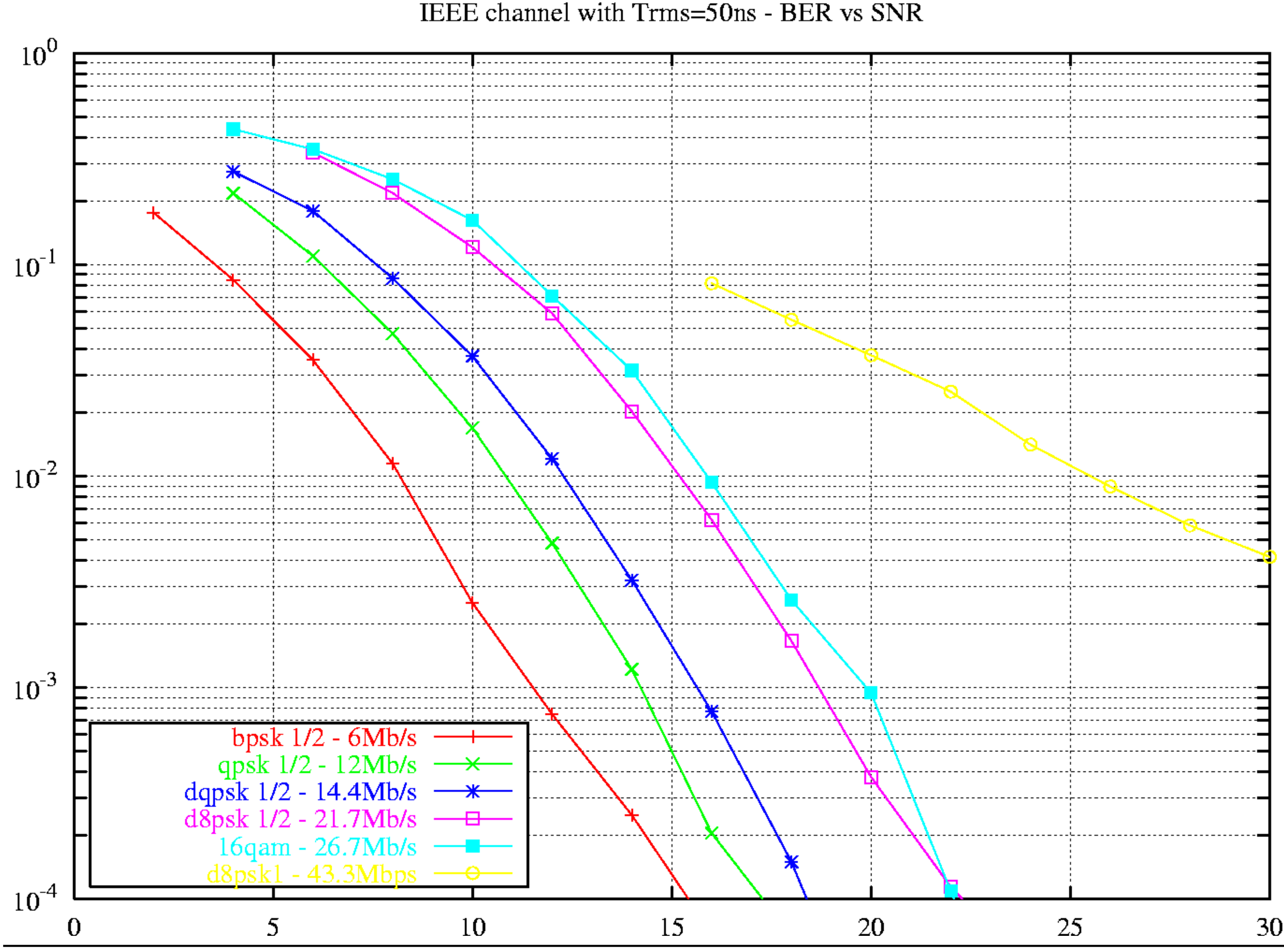
BER Performance (504 bytes packets, 5000 packets TX) for Trms=25ns



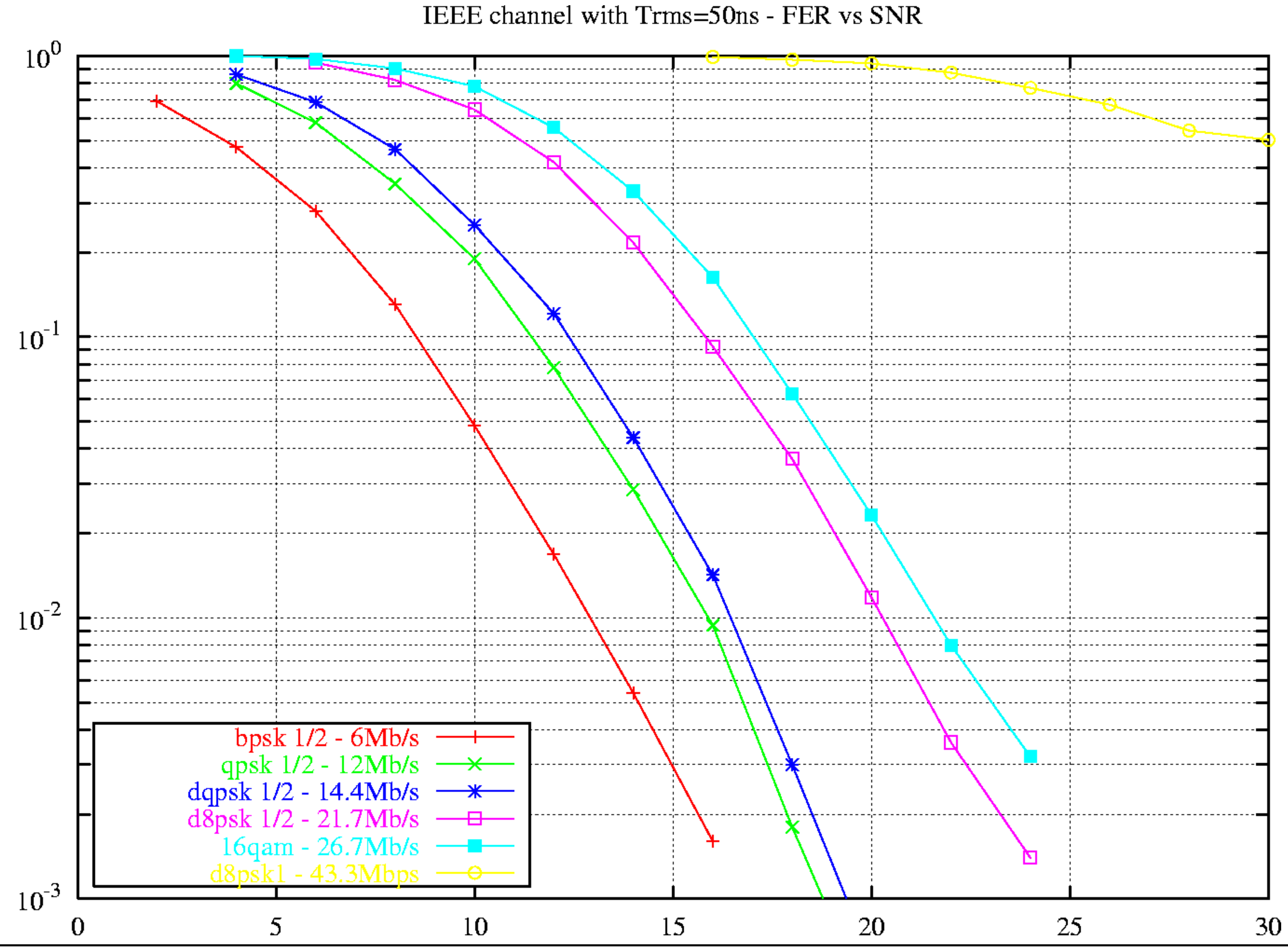
FER Performance (504 bytes packets, 5000 packets TX) for Trms=25ns



BER Performance (504 bytes packets, 5000 packets TX) for Trms=50ns



FER Performance (504 bytes packets, 5000 packets TX) for Trms=50ns



Delay spread tolerance: results for 10ns, 25 ns, 50ns

Trms = 10ns

mode	Bitrate	1%FER awgn	C/I	%ch FER>1%	max FER -5%ch
bpsk1/2-bicc	6	2.5	16.5	5%	0.1
qpsk1/2-bicc	12	5.8	19.8	5.00%	0.1
dqpsk1/2-bicc	14.4	7	21	3.60%	0
d8psk1/2-bicc	21.7	11	25	3.20%	0
16qam1/2-bicc	26.7	12	26	5%	0.008
d8psk-uncoded	43.3	21	35	10.20%	1

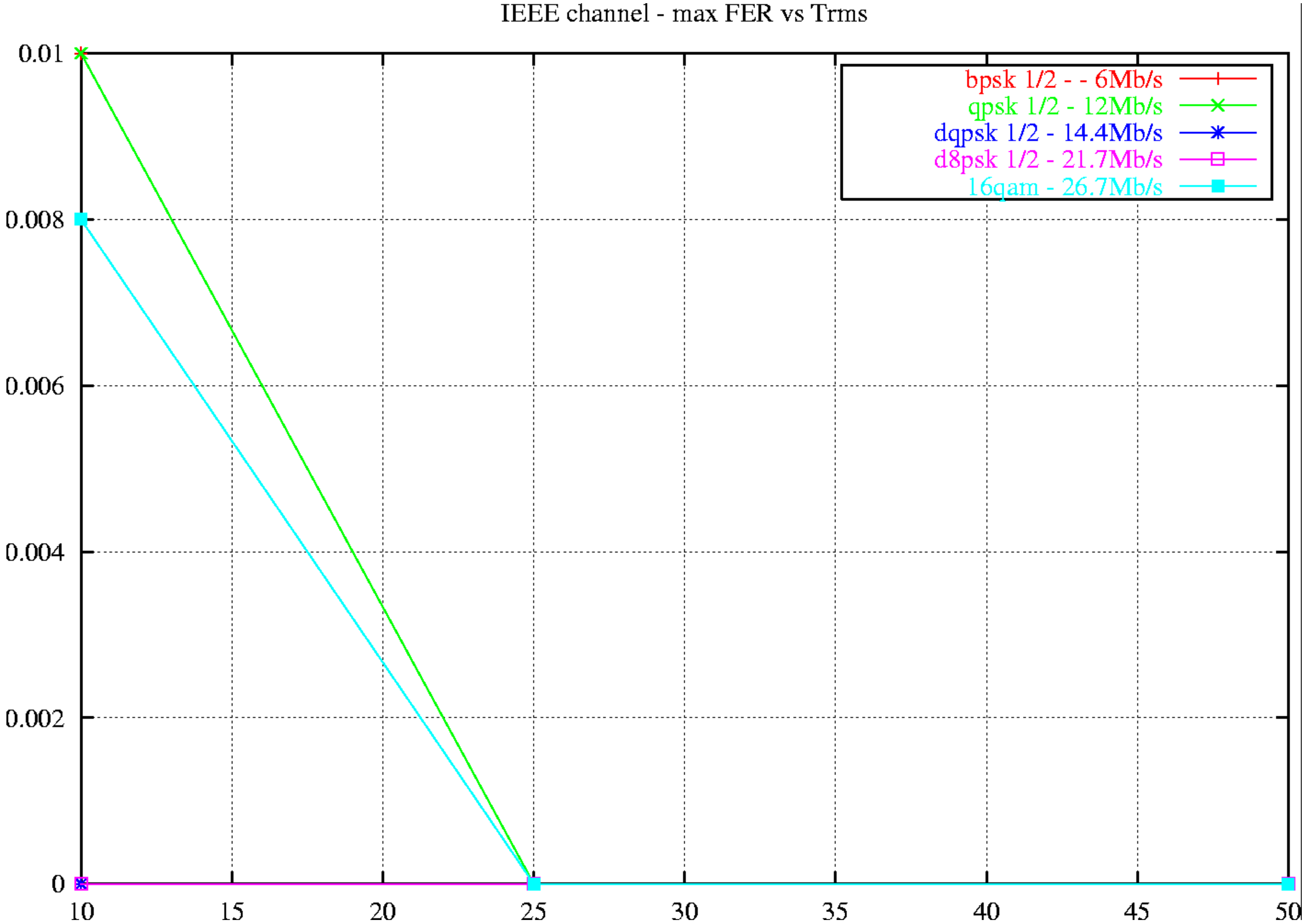
Trms = 25ns

mode	Bitrate	1%FER awgn	C/I	%ch FER>1%	max FER -5%ch
bpsk1/2-bicc	6	2.5	16.5	3%	0
qpsk1/2-bicc	12	5.8	19.8	2.08%	0
dqpsk1/2-bicc	14.4	7	21	0.98%	0
d8psk1/2-bicc	21.7	11	25	2.24%	0
16qam1/2-bicc	26.7	12	26	2%	0
d8psk-uncoded	43.3	21	35	21.50%	1

Trms = 50ns

mode	Bitrate	1%FER awgn	C/I	%ch FER>1%	max FER -5%ch
bpsk1/2-bicc	6	2.5	13	0.25%	0
qpsk1/2-bicc	12	5.8	15.8	0.00%	0
dqpsk1/2-bicc	14.4	7	16.4	0.43%	0
d8psk1/2-bicc	21.7	11	20.3	0.00%	0
16qam1/2-bicc	26.7	12	21.6	0.25%	0
d8psk-uncoded	43.3	21	35	35.80%	1

Delay spread tolerance: results for 10ns, 25 ns, 50ns (cont.)



4.9 Power Consumption

Peak power is 440mW Receive and 453mW Transmit based on a current implementation and reasonable assumptions of 0.13µ process availability.
- ADC power 25 mW (8 bits * 40 Ms/s) in line with other proposals
- RF assumes 8% efficiency PA
- MAC power in line with other proposals

Rx (mW)	*Tx (mW)*	*2000 est*
141.6		RF Rx
	166	RF Tx
99	99	VCOs
	63	Baseband Tx
77		Baseband Rx
25		ADCs
	25	DACs
0	0	RAM
100	100	MAC
442	453	Total mW

HIPERPAN evaluation matrix: general criteria

CRITERIA	Comparison Values		
	-	Same	+
Unit Manufacturing Cost ($) as a function of time (when product delivers) and volume	> 2 x equivalent Bluetooth 1	1.5-2 x equivalent Bluetooth 1 value as indicated in Note #1 ***Notes:*** 1. Bluetooth 1 value is assumed to be $20 in 2H2000. 2. PHY and MAC only proposals use ratios based on this comparison	< 1.5 x equivalent Bluetooth 1
Interference and Susceptibility	*Out of the proposed band:* Worse performance than same criteria *In band:* -: Interference protection is less than 25 dB (excluding co-channel and adjacent channel)	*Out of the proposed band:* based on Bluetooth 1.0b (section A.4.3) *In band:* Interference protection is less than 30 dB (excluding co-channel and adjacent and first channel)	*Out of the proposed band:* Better performance than same criteria *In band:* Interference protection is less greater than 35 dB (excluding co-channel and adjacent channel)
Intermodulation Resistance	< -45 dBm	-35 dBm to –45 dBm	> -35 dBm
Jamming Resistance	Any 2 devices listed jam	Handle Microwave, 802.15.1 (2 scenarios) and 802.15.3	Also handles 802.11 (a and/or b)
Multiple Access	No Scenarios work	Handles Scenario 2	One or more of the other 2 scenarios work

CRITERIA	Comparison Values		
	-	Same	+
Coexistence (Evaluation for each of the 5 sources and the create a total value using the formula shown in note #3)	*Individual Sources:* 0% *Total:* < 3	*Individual Sources:* 50% *Total:* 3	*Individual Sources:* 100% *Total:* > 3
Interoperability	False	True	N/A
Manufactureability	Expert opinion, models	Experiments	Pre-existence examples, demo
Time to Market	Available after 1Q2002	Available in 1Q2002	Available earlier than 1Q2002
Regulatory Impact	False	True	N/A
Maturity of Solution	Expert opinion, models	Experiments	Pre-existence examples, demo
Scalability	Scalability in 1 or less than of the 5 areas listed	Scalability in 2 areas of the 5 listed	Scalability in 3 or more of the 5 areas listed

CRITERIA	Comparison Values		
	-	Same	+
Size and Form Factor	Larger	Compact Flash Type 1 card	Smaller
Minimum MAC/PHY Throughput	20 Mbps (without MAC overhead)	20 Mbps + MAC overhead	> 20 Mbps
High End MAC/PHY Throughput (Mbps)	20 – 39 Mbps	40 Mbps + MAC overhead	> 40 Mbps
Frequency Band	N/A (not supported by PAR)	Unlicensed	N/A (not supported by PAR)
Number of Simultaneously Operating Full-Throughput PANs	< 4	4	> 4
Signal Acquisition Method	N/A	N/A	N/A
Range	< 10 meters	≥ 10 meters	N/A
Sensitivity	N/A	N/A	N/A
Delay Spread Tolerance	< 10 ns	25 ns	> 50 ns
Power Consumption (the peak power of the PHY combined with an appropriate MAC)	> 1.5 watts	Between .5 watt and 1.5 watts	< .5 watt

General conclusion: revised self rating proposal

00245r6P802-15_TG3-Proposal-Evaluations			
		Day/Time in La Jolla	TU 8:30
		Presenter/Doc Owner	Motorola/Radiata
		Proposal Type	PHY
		PPT/Doc	196r5
	Criteria Ref.	**Criteria**	
General	2.1	Unit Manufacturing Cost	0
Solution	2.2.2	Interference and Susceptibility	1
	2.2.3	Intermodulation Resistance	1
	2.2.4	Jamming Resistance	1
	2.2.5	Multiple Access	1
	2.2.6	Coexistence	1
	2.3	Interoperability	0
	2.4.1	Manufactureability	1
	2.4.2	Time to Market	1
	2.4.3	Regulatory Impact	0
	2.4.4	Maturity of Solution	1
	2.5	Scalability	1
	2.6	Location Awareness	0
PHY	4.1	Size and Form Factor	1
	4.2.1	Minimum MAC/PHY Throughput	1
	4.2.2	High End MAC/PHY Throughput	0
	4.3	Frequency Band	0
	4.4	Number of Simultaneously Operating Full-Throughput PANs	1
	4.5	Signal Acquisition Method	0
	4.6	Range	0
	4.7	Sensitivity	0
	4.8.2	Delay Spread Tolerance	0
	4.9	Power Consumption	1
		Total -'s	0
		Total 0's	10
		Total +'s	13