TSG-RAN Working Group 1 **_TSGR1#19(01)0291_**
Las Vegas
February 27- March 2

Agenda item: AH24, HSDPA

Source: WAVECOM, FRANCE TELECOM, NORTEL NETWORKS

Title: Stand-alone carrier – A high speed channel in downlink

Document for: Discussion and decision

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1 Introduction

A contribution introducing the notion of a stand-alone carrier [1] was presented at TSGR2#19 and was introduced in the HSDPA feasibility report TR 25.950.

A stand-alone DSCH is a DSCH on a downlink carrier that is different from the downlink carrier that carries its companion DPCH. The support of a stand-alone DSCH can be added incrementally to release 99 networks and has the potential of increasing significantly the capacity and the available bit rate in the downlink. The concept of a stand-alone DSCH is compatible with any of the HS-DSCH architecture proposed in TR 25.950 or with the release 99 architecture.

The release 99 architecture is already suitable for the support of a stand-alone DSCH. Indeed, it has no impact on the network architecture. Of course, protocols have to be extended for the support of stand-alone DSCHs, but this implies fairly limited [1].

A LS was sent to RAN WG1 which was asked to study the physical layer aspects of the stand-alone DSCH.

This contribution describes a physical layer based on an OFDM modulation that can be efficiently used for the stand-alone DSCH to achieve high data rate in downlink. Enhancements which are already under consideration for HSDPA are fully applicable to the stand-alone DSCH e.g. adaptive modulation, hybrid ARQ, etc and are not described in this contribution.

2 Proposed modulation scheme

Enhancements that are already under consideration for HSDPA are fully applicable to the stand-alone DSCH e.g. adaptive modulation, hybrid ARQ, etc. In addition to them, a multi-carrier modulation such as OFDM (Orthogonal Frequency Division Multiplexing) may be used as an alternative to WCDMA, to achieve very high transmission data rates

2.1 OFDM overview

OFDM is very efficient in time and frequency dispersive environments e.g. in environments suffering from multi-path propagation and Doppler effect, especially when used with channel coding and interleaving (Coded OFDM, denoted COFDM hereafter). The principle of OFDM is to split the high bit rate information to be transmitted over a large number of carriers, in such a way that the modulated symbols will be much longer than the delay spread [2]. This makes the modulation intrinsically robust to multi-path. Moreover, orthogonality is guaranteed between all sub-carriers composing the frequency multiplex, and between consecutive OFDM symbols. This enables to define the OFDM modulation on a time-frequency frame which density is maximal (overlapping sub-carriers spectrums). This multi-carrier modulation is therefore very spectral efficient.

To combat multi-path effect, a guard interval (also called cyclic prefix) is appended to each OFDM symbol. It absorbs all the inter-symbol interferences. In other words, the channel becomes flat on each sub-carriers. However, frequency selectivity still exists on the overall signal bandwidth: some carriers suffer from deep fades, while others are correctly transmitted. To handle it, coding and interleaving are used in combination with OFDM modulation (COFDM technique [2]).

Applying these techniques to OFDM leads to averaging local fadings over the whole signal bandwidth and over the time interleaving depth. Frequency selectivity is then turned into an advantage, which corresponds to frequency diversity. The same channel coding schemes as those defined for WCDMA can be used, e.g. convolutional code and turbo code.

OFDM is efficiently implemented by the use of Fast Fourier Transform in the transmitter and receiver.

The principle of OFDM transmission chain is recalled in the figure 1 below.

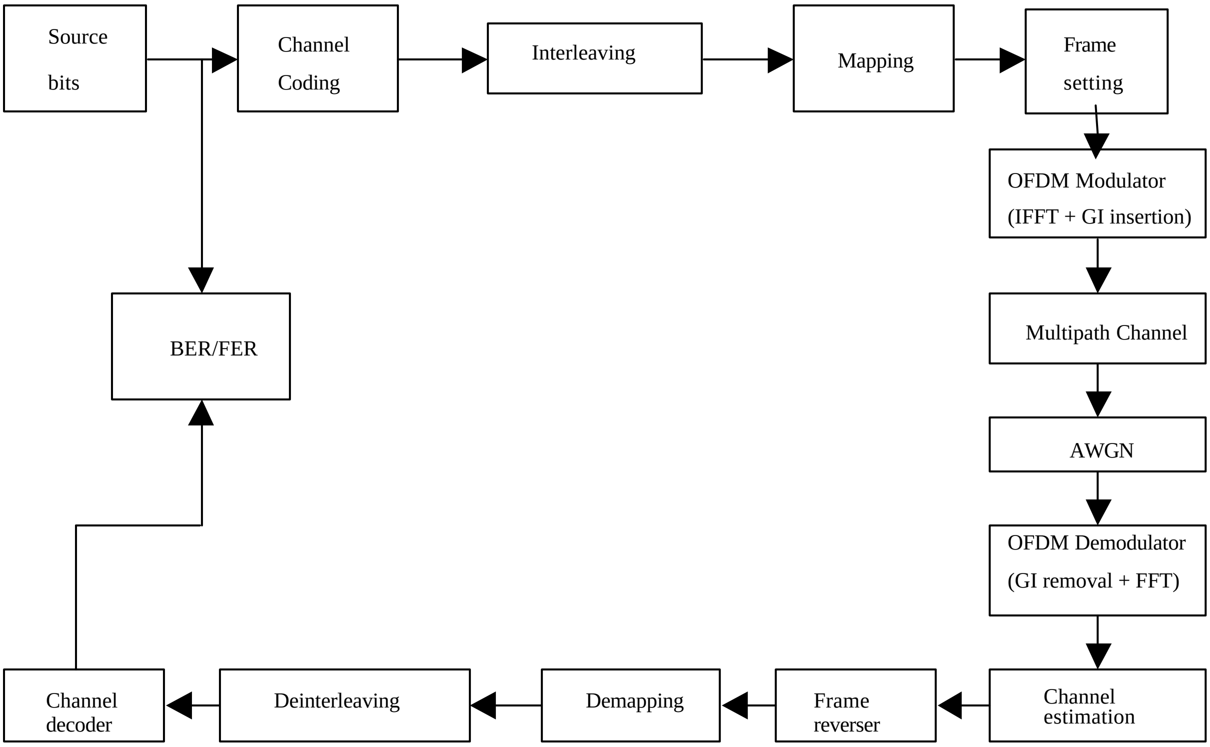

Figure 1: transmission chain synoptic

More details about this multi-carrier modulation parameters can be found in § 7 (Annex B).

2.2 Physical channel parameters

2.2.1 COFDM parameters

The OFDM modulation is characterized by a few parameters that may be optimized with regard to the propagation environment and to the system requirements ([2], [3]). Different sets of parameters, say Nc, may be defined, each corresponding to a physical channel, which is then characterised by the set of values $(T_S, ??_0)$, where T_s is the symbol duration and v_0 the inter-carrier spacing. In our study we proposed 3 different physical channels (Nc=3), each corresponding to several groups of propagation channels defined in [4]. They are represented in Table 1. This optimization makes the transmission more efficient and can be interpreted as another degree of freedom for the radio link adaptation given by the AMCS.

Of course, Nc can also equal 1, i.e. one set of parameters for all propagation conditions. This single set of parameters must in that case verify conditions (1) and (3) hereafter in all propagation environments.

More precisely, parameters to be set are:

?? Signal bandwidth Bsig
?? Net bit rate Db
?? Number of bits per constellation point : m
?? Useful symbol duration : Tu
?? Guard interval : ?g
?? Coding rate : R

Generic constraints due to propagation to be fulfilled are:

(1) Guard interval (GI) Tg > $?_{max}$
(2) Ratio Tu/Tg as high as possible to optimize the spectral efficiency
(3) Channel invariant on an OFDM symbol and for each sub-carrier :
    (3.1) Ts (=Tu+Tg) << 1/2Fd
    (3.2) $?_0 << 1/?_{max}$ (note that (1) and (2) imply (3.2))

Besides, system designing imposes:

?? Channel bandwidth Bsig ~5 MHz
?? Net bit rate of at least 6 Mbps
?? A frame (10 ms) is a multiple of Ts (=Tu + Tg)

In that context, optimised parameters can be those as precised in Table 1. These are under the hypothesis that a net bit rate of more than 6 Mbps is achieved while imposing that QPSK is transmitted over all sub-carrier (to guarantee robustness of the system to highly frequency selective and time varying channels).

Note: the stand-alone DSCH uses the same frame structure as the one defined in UTRA: a 10 ms radio frame is divided into 15 slots of 0.667 ms.

Physical Channel	Type 1	Type 2	Type 3
UMTS propagation conditions (vehicle speed: km/h)	Indoor A (3, 10) Indoor B (3, 10) Out-In A (3, 50, 120)	Out-In B (3, 50, 120) Vehicular A (50, 120, 250)	Vehicular B (50, 120, 250)
3GPP propagation conditions*	Cases 1, 3, 4, 5		Case 2
Useful symbol duration T_u (?s)	15.625	78.125	140.625
Guard interval duration T_g (?s)	1.04	5.2	26.04
T_g / T_u (%)	6.7	6.7	18.6
Overall symbol duration $T_s = T_u + T_g$ (?s)	16.67	83.325	166.67
Carrier separation $?_0$ (kHz)	64	12.8	7.11
FFT size	120	600	1080
Number of sub-carriers	80	400	720
Number of OFDM symbol per frame (10 ms)	600	120	60
Constellation	QPSK	QPSK	QPSK
Channel bit rate	9.6	9.6	8.625

Table 1 : OFDM physical channel parameters according to the propagation environment.

(*) : In this example, system parameters were optimized regarding UMTS propagation conditions defined in [4]. However, these parameters can be used for 3GPP cases as indicated in Table 1.

Examples for the channel coding parameters for the performance evaluation are :

Physical Channel	Type 1	Type 2	Type 3
Coding rate	3/4	3/4	4/5
Channel bit rate	9.6	9.6	8.625
User bit rate**	7.2	7.2	6.9

Table 2 : Proposed coding schemes

(**) : In this example, the overhead represented by the pilot symbols is not accounted for. This will typically represent 10% of the bit rate.

2.3 Frame setting

Synchronization and channel estimation are achieved by the use of reference sub-carriers (also called pilots) that are scattered in the time-frequency domain as shown in the figure 3 below. Those reference symbols can be boosted (i.e. transmitted with higher power than payload sub-carriers) in order to achieve better performances at the channel estimation stage.

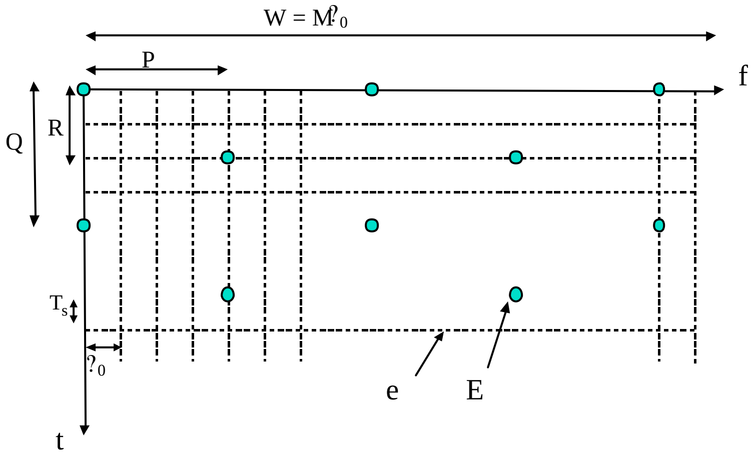

Figure 3: reference sub-carriers

P: normalized pilots spacing in frequency
Q, R: normalized pilots spacing in time
e: average energy per symbol
E: average energy per pilot symbol
W: signal bandwidth

2.4 Multiple access

Packet data transmission is achieved through the stand-alone DCSH using OFDM. Multiple users is obviously handled within the scope of this solution.

The packet data radio transmission is realized via the allocation of a Multi Carrier Block. The MCB is equal to the number of OFDM symbols (NTs) multiplied by the number of sub-carriers in frequency ($M?_0$). The MCB identification is realized through the knowledge of the set of values $??n_1, m_1 ?, ?n_2, m_2 ??$, as illustrated on figure 2. This MCB allocation can be viewed as a mix of (Orthogonal) FDMA and TDMA.

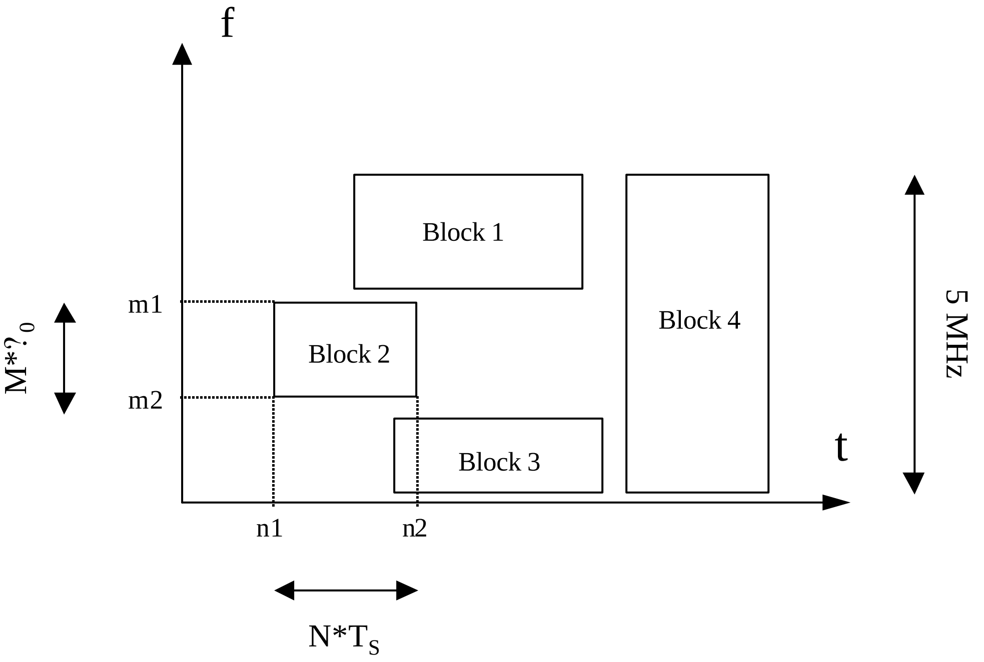

Figure 2: Multi Carrier Block identification

2.5 Performances overview

Using OFDM, the stand-alone DSCH will efficiently support high data rates and mobility. Simultaneous transmission of many different types of data streams, e.g. video, voice and data will be possible.

While using QPSK, which is a very robust modulation, and with a coding rate of 3/4, we can achieve 7.2 Mbps in 5 MHz. This figure is based on the optimized parameters we defined for our study, which are given in §7 (Annex B). This data rate has to be compared to the 2Mbps offered with WCDMA technique.

This net bit rate can still be increased while using higher order modulations and, if needed, coding rate. For instance, using 16 QAM instead of QPSK (while coding rate is still 3/4) leads to 14.4 Mbps in 5 Mhz. In other words, a link adaptation concept, based on adaptive modulation and coding scheme (AMCS) can be considered for the OFDM modulation (see e.g. [5])

Moreover, larger bandwidth can also easily be considered. For instance using QPSK in 20 MHz leads to a peak bit rate of 26 Mbps.

In addition those bit rates are still available in a real mobile environments up to vehicle speed of 250 Km/h.

All these results are valid without taking into account enhancements that are already under consideration for HSDPA and would also be fully applicable to a stand-alone DSCH e.g. adaptive modulation, hybrid ARQ, etc.

More details about simulation parameters and results can be found in § 6 & 7 (Annexes A & B). Note that the results are produced using UMTS channels defined in [4]. These channels are more time varying than those defined for 3GPP (cases 1 to 5), recalled in the TR 25.848. Hence, one can suppose that the presented results might be improved on 3GPP channels.

Note : OFDM spectral efficiency can be further increased, by shaping each sub-carrier with a prototype function optimally localized in the time and the frequency domain [6]. This is an alternative to the classical OFDM (OFDM with guard interval), which is also worth being studied.

3 UE's impacts

3.1 Base-band architecture

The complexity in the hardware structure of the receiver is evaluated here, assuming that COFDM is used to achieve high data rates over the stand-alone DSCH.

In that case, the UE must be able to demodulate both the WCDMA and the received COFDM signals.

Additional complexity is given in terms of silicon surface. The services taken into account are voice and data (fast internet, home shopping, banking, video on demand..). A dedicated processor whose existence is not related to the use of OFDM over the stand-alone DSCH performs special applications such as video conferencing.

Hardware complexity notably depends on the channel estimation technique used. In our case, channel estimation is performed per block by using scattered pilots and a two-dimensional interpolation technique.

The silicon reference area corresponds to a baseband component performing both WCDMA, GSM and GPRS.

For a 100 mm2 reference component, it was evaluated that the additional silicon area due to OFDM is only 3.5%.

3.2 Radio architecture

The UE radio architecture depends on the impacts of the WCDMA transmission and reception on the OFDM reception. and vice versa.

<u>RX WCDMA and RX OFDM:</u>

If the stand-alone and the RX WCDMA bands are distant at least 30 MHz, while using SAWs one can couple the two bands at the stage of the duplexer.

<u>TX WCDMA and RX OFDM:</u>

Depending on the distance between the TX WCDMA band and the stand-alone band the following scenarii are possible:

- one antenna is sufficient (large enough separation i.e. more than 50 MHz)
- 2 antennas or one antenna with a specific duplexer (close bands).

These conclusions are obviously to be re-examined according to the progress of radio technologies.

4 Concluding Remarks

In this contribution an OFDM based stand-alone DSCH is presented and detailed. OFDM enables high data transmission with or without mobility.

As an example, physical channel parameters as well as a frame setting are proposed. All the COFDM parameters are optimised depending on the propagation conditions. As an alternative to this, the parameters obtained for the worst case of Doppler effect and delay spread can obviously be used for every other case of propagation.

By using OFDM, instead of sharing codes as it is the case for WCDMA, users are both sharing the frequency and the time resources. Time and frequency resource is optimised and flexible depending on the users requirements.

The complexity of the hardware is also presented. The required changes in the stand-alone receiver lead to a very reasonable additional complexity.

Finally link level simulation assumptions and results are given. While using QPSK, we reach for efficient data transmission with a net bit rate of 7.2 Mbps up to 250 Km/h. As the propagation environments simulated here are worse in terms of mobility than those specified in TR 25.948, results should be actually improved on 3GPP propagation environments. Higher order modulations such as 16 QAM and different coding rates can be used to achieved higher data rates and enhancements that are already under consideration for HSDPA are fully applicable to the stand-alone DSCH.

As an OFDM based stand-alone DSCH is feasible, it is proposed to document the stand-alone DSCH in the RAN 1 technical report for consideration of the concept at RAN level. A proposal for update of the TR is available in R1-01-xx4

5 References

[1] *"Support of stand-alone carrier for DSCH"*, TSG- RAN WG2 #19 (00) R2A010002, Nortel Networks

[2] R. Lasalle, M. Alard. "*Principles of modulation and channel coding for digital broadcasting for mobile receivers*", EBU Review no. 224, pp168-190, August 1987

[3] D. Lacroix, D. Castelain, *"A Study of OFDM Parameters for High Data Rate Radio LAN's"*, Proceedings of VTC2000-Spring, Tokyo, May 13-18 2000

[4] ITU 3003-320 Annex B

[5] *"Broadband Radio Access Networks (BRAN); HIPERLAN Type 2 Technical Specification; Physical (PHY) Layer"*, ETSI DTS/BRAN-00 23003 V0.k, October 1999

[6] B. Le Floch, M. Alard and C. Berrou, *"Coded Orthogonal Frequency Division Multiplex"*, Proceedings of the IEEE, Vol. 83, N°6, june 1995

6 Annex A: Link level simulation parameters

The table 2 below summarizes the link level simulation assumptions.

Parameter	**Value**	**Comments**
Carrier frequency	Around 2 GHz	To be defined
Sampling Frequency	7.68 MHz	
Channel bandwidth	5 MHz	
Propagation condition	AWGN, IB10, OIA50, OIA120, OIB120, VA50, VA250	Worst cases than the defined environments in TS 25.201 and TS 25.202. Others results will be given considering the more favorable propagation models given in those two TRs.
Vehicle speed	10/50/120/250 kmph	
HSDPA frame length	10 ms	
Channel Estimation	Ideal	First step
Fast fading model	Jakes spectrum	Generated by Jakes
Symbol period	C.f. table 1 in § 2.2.1	
Inter-carrier spacing	C.f. table 1 in § 2.2.1.1	
Channel coding	Convolutional code (K=7, [133, 171])	Turbo-code : to be simulated
Channel code rate	3/4 and 4/5 for Vehicular B	Channel code rate will vary depending of the desired throughput (AMCS)
Interleaving depth (TTI)	3.33 ms (5 slots)	First step; 10 ms to be simulated
Number of bits per symbol constellation	2 (QPSK)	Higher level constellation can be achieved, depending on the required throughput e.g. depending on the service (AMCS).
Pilot energy / data symbol energy	$\frac{E}{e} ? \sqrt{N ? 2}$	N is the number of data symbols per pilot symbol.
Number of simulated bits	10 and 50 km/h: 10 Mbits 120 and 250 km/h: 5 Mbits	
Information bit rate	6 Mbps at least	

Table 2: link level simulation assumptions

In addition, we may notice that the channel variation (due to Doppler) was simulated in a continuous way .

Namely, the channel is modelled as

$$r(t,?) ? \overset{Npath?1}{\underset{i?0}{?}} c_i(t).s(? ? ?_i) ? n(?)\,,$$

whereby $n(?)$ is the Gaussian noise, $s(?)$ the transmitted signal, $r(t,?)$ the received signal and, for each path, $c_i(t)$is a complex Gaussian process correlated in time according to the Doppler spectrum (the c processes are independent from each other). This coefficient can, for instance, be modelled as white Gaussian noise filtered by a Doppler filter.

7 Annex B: Link level simulations results

Propagation environment	IB 10km/h	OIA 50km/h	OIA 120km/h	OIB 120km/h	VA 50km/h	VA 250km/h	VB 120km/h
Useful symbol duration Tu (? s)	15.6	15.6	15.6	78.1	78.1	78.1	141
Guard interval Tg (? s)	1.04	1.04	1.04	5.2	5.2	5.2	26
Total symbol duration Ts (? s)	16.64	16.64	16.64	83.3	83.3	83.3	167
Inter-carrier spacing ?$_0$ (kHz)	64	64	64	12.8	128.	12.8	7.1
FFT size	120	120	120	600	600	600	1080
Number of modulated sub-carrier per OFDM symbol	80	80	80	400	400	400	720
Signal bandwidth (MHz)	5.12	5.12	5.12	5.12	5.12	5.12	5.12
Coding rate	3/4	3/4	3/4	3/4	3/4	3/4	4/5
Channel bit rate (Mbps)	9.6	9.6	9.6	9.6	9.6	9.6	8.625
User bit rate (Mbps)*	7.2	7.2	7.2	7.2	7.2	7.2	6.9
Spectral efficiency (b/s/Hz)	1.4	1.4	1.4	1.4	1.4	1.4	1.35

Table 3: data rates (Mbps) using QPSK

(*) Please note that this throughput is a maximum, which supposes that all sent sub-carriers convey useful information. In reality, some of them will be dedicated to channel estimation and synchronization (see §2.2.4). This should however not end in more that 10% loss in spectral efficiency.

Note: the results on OFDM provided in this contribution come from the work achieved within a French cooperative research projet (RNRT) named MODYR.

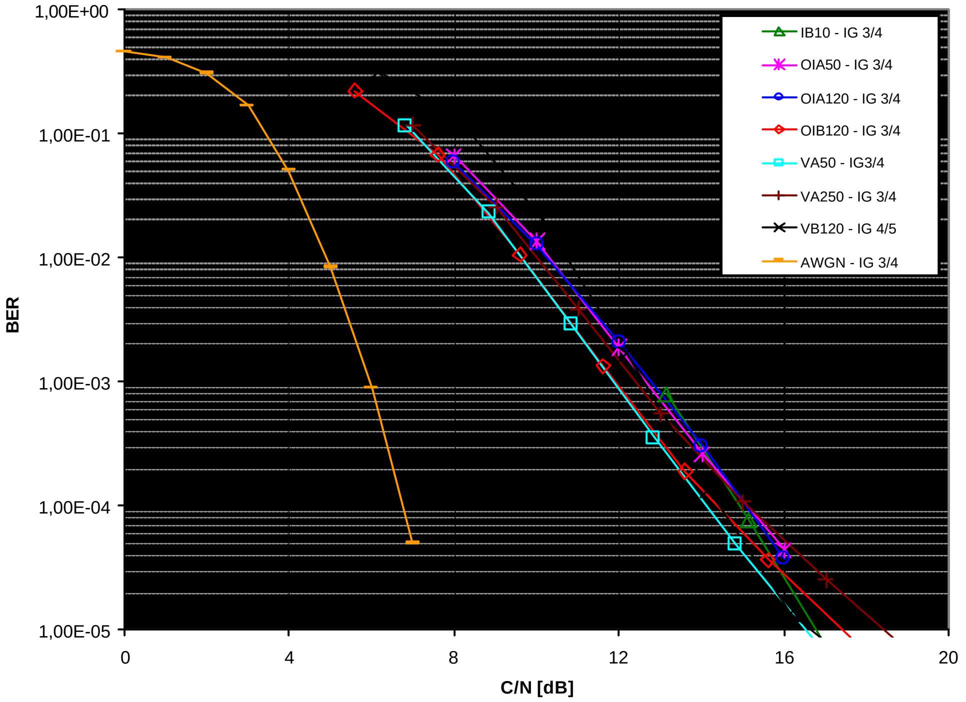

Figure 4: COFDM performances

Environment propagation	C/N (dB)
AWGN	6.3
IB 10	14.9
OIA 50	15.1
OIA 120	15.1
OIB 120	14.4
VA 50	14.1
VA 250	15.1
VB 120	14.4

Table 4: Performances of a COFDM system for a BER of 10^{-4}