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Title	**Initial OFDM/OFDMA PHY proposal for the 802.16.3 BWA**
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Re:	Call for Contribution for Initial PHY proposals to develop the TG3 PHY specification; issued 2000-09-15.
Abstract	We give a description of an OFDM/OFDMA system, which is planned to combat the wireless channels for under 11GHz. This PHY proposal is submitted for consideration for the development of the TG3 PHY specification.
Purpose	This proposal should be used as the baseline for the PHY specification of the TG3.
Notice	
Release	
Patent Policy and Procedures	

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Initial OFDM/OFDMA PHY Proposal for the TG3 PHY development

Dr. Zion Hadad, Yossi Segal and Itzik Kitroser

1. Introduction

The following contribution proposes a basis for a wireless PHY layer enabling broadband services to users in a Point to Multi-Point topology. The proposed PHY layer is based on the ETSI DVB-T (Digital Video Broadcasting Terrestrial) standard for the downstream (chips of DVB-T are manufactured today by: LSI Logic, Philips, Simense, STM, Fujitsu, Conexant, Teracom, Runcom and others, while set-top boxes are manufactured by Philips, Nokia, Pace and others), which has proven to be a well-fitted standard for low frequencies and poor channels, while the upstream is based on the DVB-RCT (Return Channel Terrestrial) which uses the TDMA/Orthogonal Frequency Division Multiple Access (TDMA/OFDMA), the DVB-RCT spec is now under last approvals of the DVB technical module, in it's preparation several companies as France Telecom, TDF, RTE, CANAL+, STM , LSI-LOGIC, PHILIPS, SISCO, Nortel, COM21 and RUNCOM have participated. The following proposal has many advantages over a regular OFDM system and many over a Single Carrier system; the proposal has excellent Coverage, Reuse, Capacity, Cost involves simple installation and addresses spectrum allocations suitable for FDD or TDD duplexing. In this proposal we adopt some of the DVB-T and DVB-RCT modes, and adapt them to extend the system to TDD and H-FDD modes also, as well as adaptation for different bandwidths and rates required in some other bands. This proposal can fit the licensed and unlicensed bands (HUMAN study group).

2. Channel bandwidth

The channel bandwidths for the frequencies below 11GHz differ between several areas of the world:

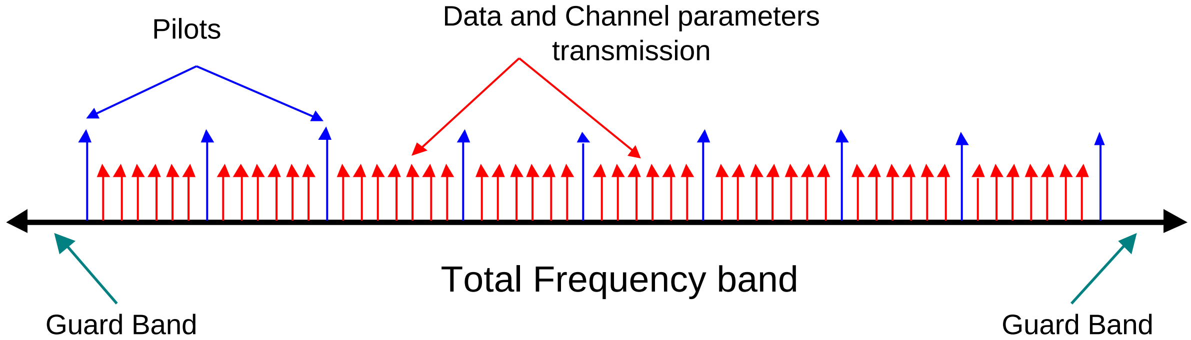
- In the US and other places in the world 1.5, 3, 6, 12MHz are recommended
- ETSI recommends channel bandwidth of 1.75, 3.5 ,7 ,8 ,14, 28MHz

For these bandwidths several symbol rates and bit rates can be considered

Symbol Rate (MSymbols/Sec)	Channel Bandwidth (MHz)
1.4	1.5
1.65	1.75
2.85	3
3.3	3.5
5.7	6
6.6	7
7.6	8
11.4	12
13.2	14
26.4	28

3. Down Stream OFDM symbol

The down stream, which is based on one mode of the DVB-T standard ('2k' mode), is based on a 2048 points FFT, encapsulating MPEG-2 data frames inside. The OFDM symbol is illustrated in the next schematics:

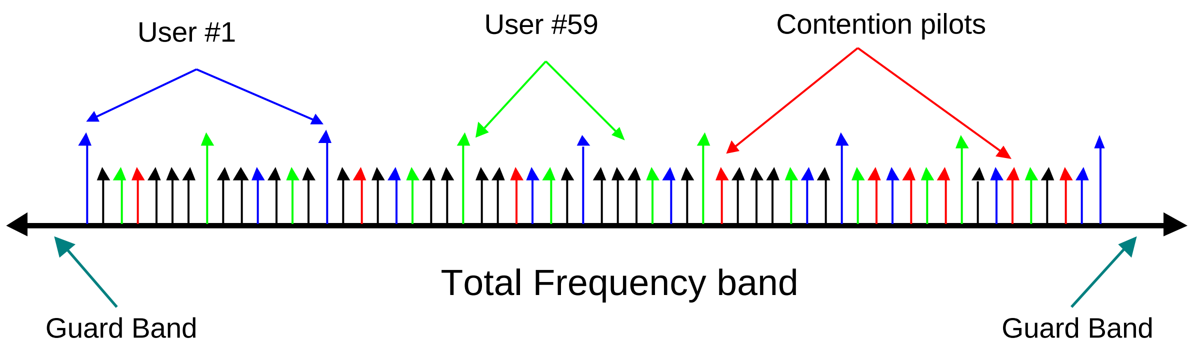


From this we can see that the symbol in frequency is build from carriers which are zeroed, these regions are called Guard Bands, the purpose of the guard band is to enable the signal to naturally decay and create the FFT "brick Wall" shaping. The other carriers are used for data transmission, pilots (for channel estimation) and the transmission of the physical parameters. The total overhead for carriers, which are not used for data transmission, is low and equals to 11% of all carriers. Each symbol when transmitted in time has it's own Guard Interval (GI), which is the OFDM's protection against Multipath.

This scheme has been proved to be very robust against channels in frequencies lower then 1GHz (for higher frequencies it is even better). This scheme has several GI that enables the optimization and adaptation of the transmission to the channel propagation delay. As an example for the 8MHz channel the propagation delay that can be handled is 7-56usec, which will enable to tackle propagation delay for frequencies of 0.3-11GHz.

4. Up Stream OFDMA symbol

The up stream which is based on the DVB-RCT using the OFDMA principle, the main idea is that an OFDM symbol which is based on a 2048 points FFT, is divided into sub sets of carriers. We denote a sub set of carriers as a Sub-Channel. Then we can divide the all-usable carriers (beside the Guard Bands) to several sub-Channels. If we use 1711 carriers and 29 carriers per Sub-Channel then we achieve 59 Sub-Channels. These are illustrated in the next scheme:



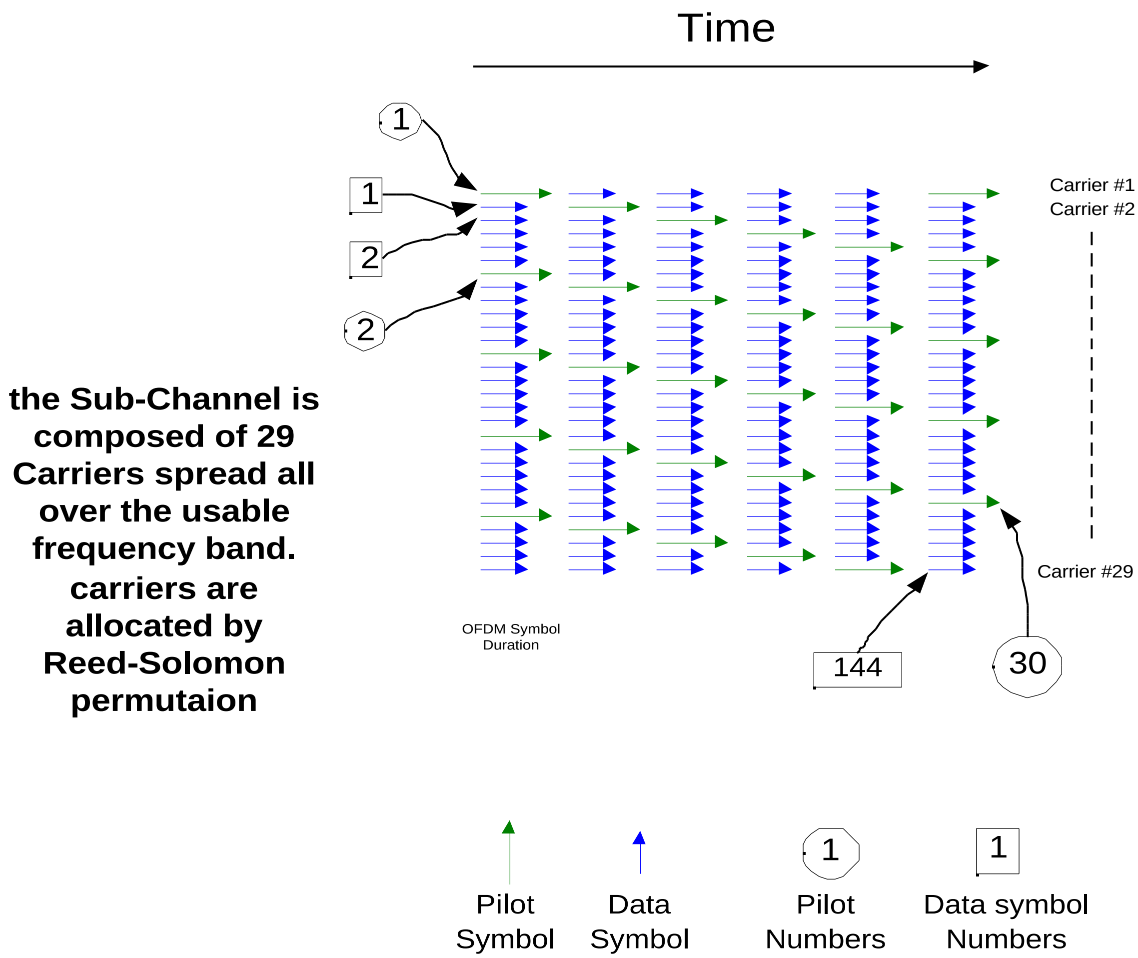
These Sub-Channels are the basic allocation unit, and the smallest granularity that a user can be allocated. Each allocation of Sub-Channel can be allocated for several OFDM symbols in such a way that the estimation of each Sub-Channels is done in frequency and time. Moreover the allocation of carriers to Sub-Channel is done by special Reed-Solomon series, which enables the optimization and dispersion of interfering signals inside a cell and between adjacent cells. This powerful technique enables a better Reuse Factor, Better throughput as well as fighting Doppler shifts and statistically spread interferences.

5. Time and Power Ranging

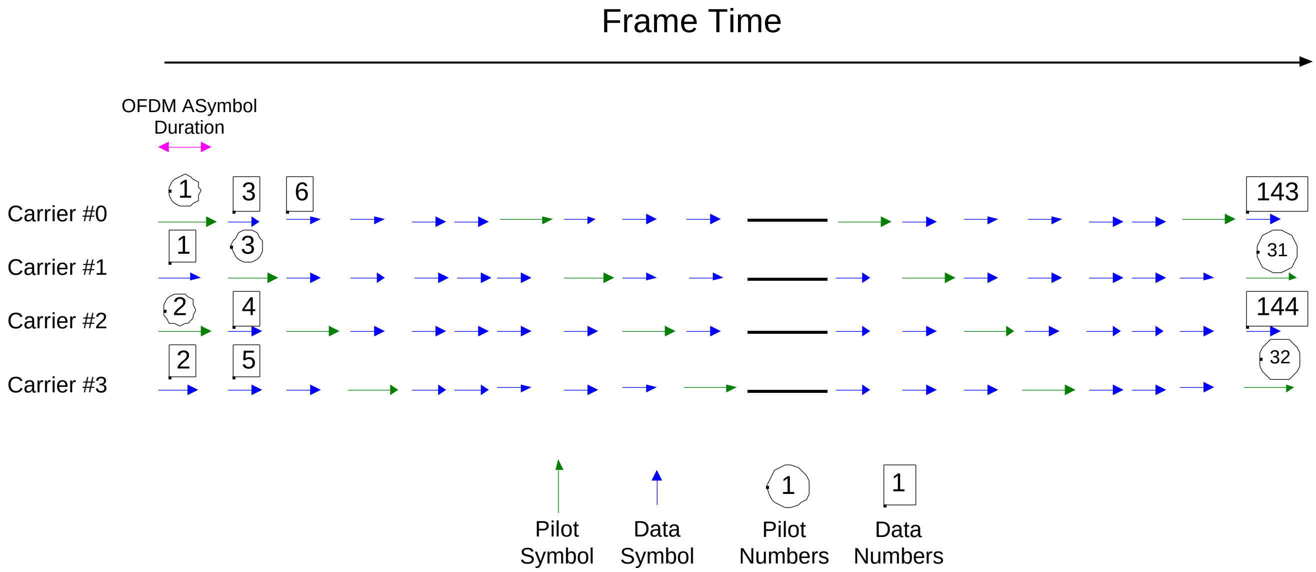
Time and Power ranging is performed by allocating several Sub-Channels to one Ranging Sub-Channel upon this Sub-Channels users are allowed to collide, each user randomly chooses a random code from a bank of codes. These codes are modulated by BPSK upon the contention Sub-Channel. The Base Station can then separate colliding codes and extract timing and power ranging information. The time and power ranging allows the system to compensate the far near user problems and the propagation delay caused by large cells (up to 50Km). We should mention that the propagation time when using for example a 8MHz channel is within one OFDMA symbol only (150usec where the OFDMA symbol lasts about 230usec).

6. Up Stream Frame Structure

The up stream frame structure is composed from allocation of Sub-Channels in the frequency domain for several OFDMA symbols in the time domain. The frames used consists of 144 data symbols and several more pilot symbol for estimation (the amount depends on the frame structure and the number of carriers per Sub-Channel), the Ratio between data and pilot symbol is about 1:6. Mode 3 of the DVB-RCT for this kind of allocation can be seen in the next figure:



This scheme of allocation serves both frequency and time diversity. Additionally the allocation can differ to fewer carriers comprising a smaller Sub-Channel but more OFDMA symbols in time. And can be seen in the next figure:



The basic 29 carriers allocation is spread all over the usable frequency range and uses special Reed-Solomon permutation to make the Sub-Channels independent as possible from each other (allocation of 4 carriers, for the mode of 4 carriers, are sub-sets of the basic Sub-Channels).

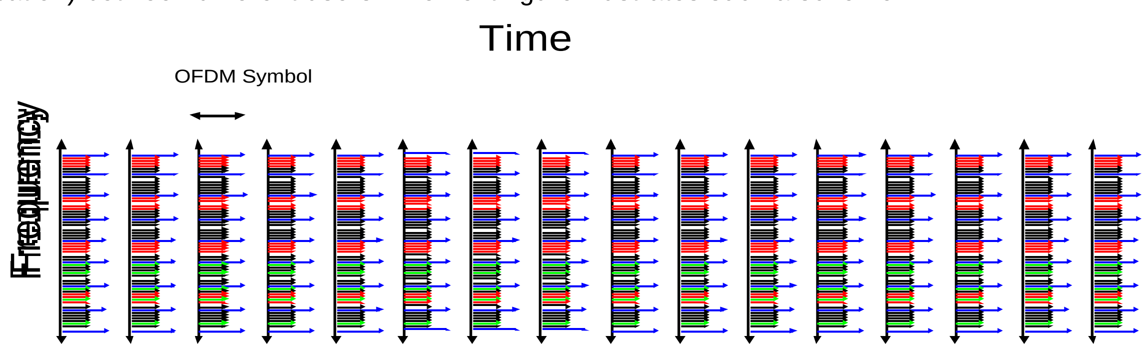
The advantages in using these allocations are the following:

- Keeping the number of useful symbols constant.
- Achieving time and frequency diversity
- Allowing more power concentration or more frequency diversity as the user needs.
- Lowering the power amplifier demands and it's cost
- Longer ranges and better SNR where possible
- Planned for interference desperation and better reuse factor

7. Multiple Access Schemes and Multiplexing

For the down stream a Time Division Multiplex (TDM) is used where all the data is contained in the OFDM symbols, and each user after decoding the data extracts the relevant information.

For the Up stream TDMA/OFDMA is used where OFDM symbols are shared both in time and in frequency (by Sub-Channel allocation) between different users. The next figure illustrates such a scheme:



Each color in the frequency domain represents a Sub-Channel. One allocation includes allocating at least one Sub-Channel for duration of 6 OFDM symbols, this compromise is the best solution between tackling burst noise and minimizing the delay (for 8MHz channel a delay of 1.5msec). The allocations of Sub-Channels to users are based upon the user's needs, and upon demand. User can be allocated from 1 to the maximum available Sub-Channels.

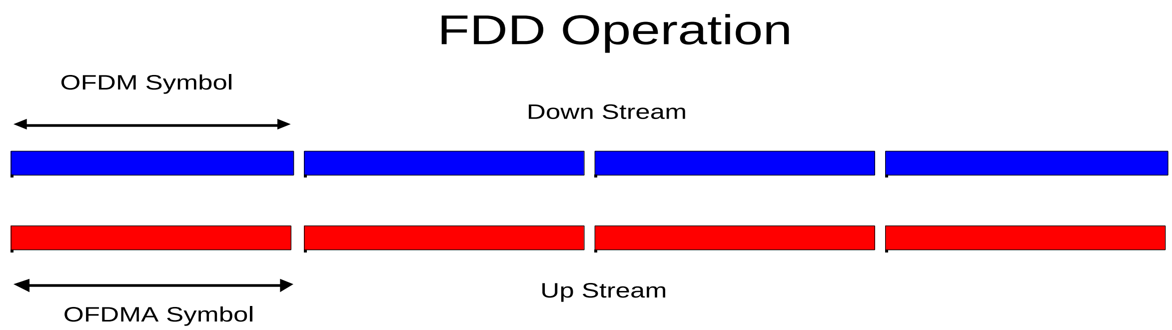
8. Duplex scheme

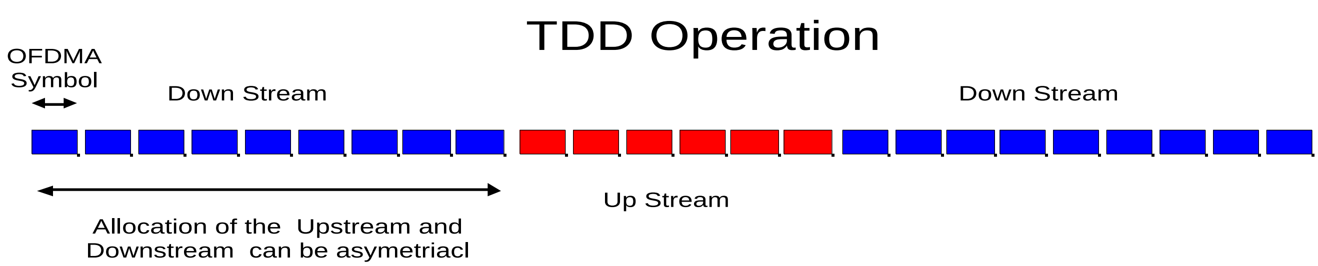
The duplex scheme for the proposed system can be TDD, FDD or H/FDD (which are expansions to the FDD modes of the DVB-RCT and the broadcasting mode of the DVB-T).

In FDD/HFDD mode each stream is independent from the other. Each stream can use it's own GI duration and operation.

For a TDD 8MHz symmetrical mode the downstream can transmits for approximately 1.5msec OFDM symbols and in the next 1.5msec there is transmission of the OFDMA symbols (taking as an example a symmetrical TDD mode using 8MHz channels), for this mode it is preferable to use Sub-Channel allocations of 29 carriers in order to keep the up stream frame time short. The time of the up stream and down stream can vary depending on asymmetry needed, channel bandwidth used and GI for the OFDM/OFDMA symbols.

In any operating mode the users are synchronized to the base in such a way that the users transmitting in the same OFDMA symbol reaches the Base Station with certain accuracy in time, therefore they can be treated in a single FFT operation.





9. Adaptive Modulation

The modulation used both for the uplink and downlink are QPSK, 16QAM and 64QAM. These modulations are used adaptively in the downlink and the uplink in order to achieve the maximum throughput for each link.

The bit rates (before coding and estimation) that could be achieved by the downlink and uplink, taking the DVB-T model as reference are presented by the next table:

Channel Bandwidth (MHz)	Symbol Rate (Msymbols/Sec)	Bit Rate using QPSK (Mbps)	Bit Rate using 16QAM (Mbps)	Bit Rate using 64QAM (Mbps)
1.5	1.6	2.85	5.7	11.4

1.75	1.65	3.3	6.6	13.2
3	2.85	5.7	11.4	17.1
3.5	3.3	6.6	13.2	19.8
6	5.7	11.4	22.8	34.2
7	6.6	13.2	26.4	39.6
8	7.6	15.2	30.4	45.6
12	11.4	22.8	45.6	68.4
14	13.2	26.4	52.8	79.2
28	26.4	52.8	105.6	158.4

For the up stream each user is allocated a modulation scheme, which is best suited for his needs. Therefore in one OFDMA symbol several modulations scheme are possible. These techniques of adaptive modulation are well known and wells supported in the MAC layers.

10. Adaptive Coding

The proposed coding scheme differs between the up stream and the down stream. The concatenated Reed Solomon (204,188,8) and Convolutional coding (k=7,G1=171,G2=133) with convolutional interleavers between composes the down stream coding. The coding rate can be manipulated by changing tha puncture rate of the Convolutional coding between the following rates: _, 2/3, _, 5/6, 7/8.

While for the up stream there are two coding scheme possible:

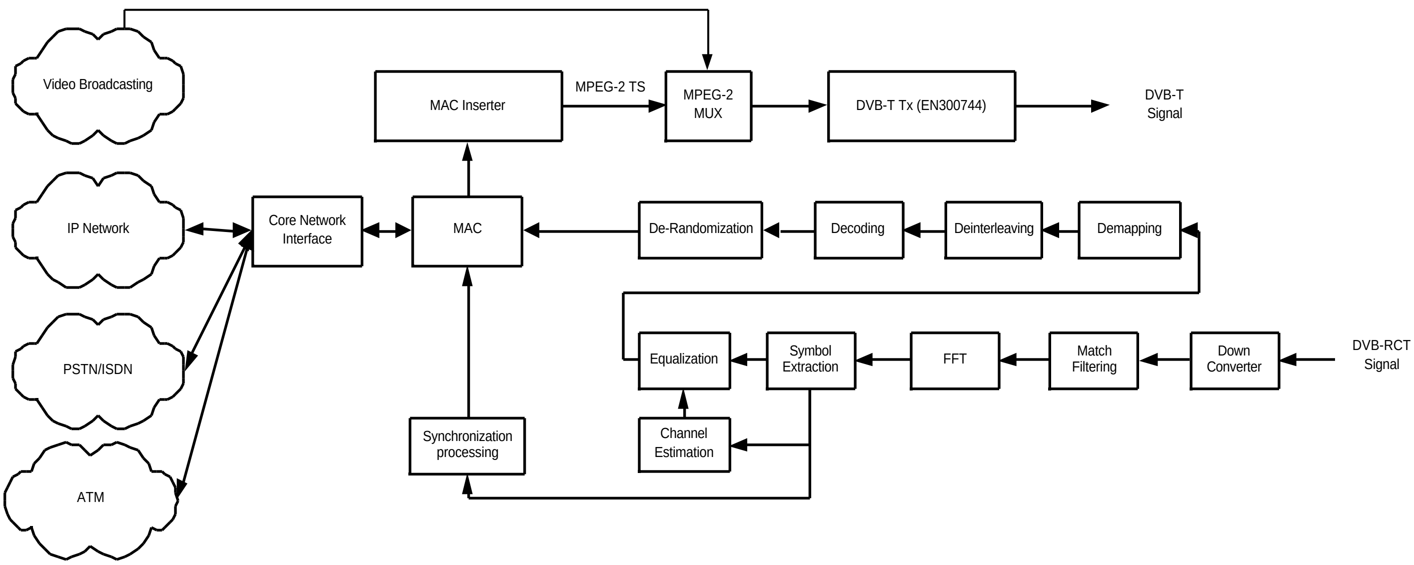
- Concatenated Reed-Solomon (63,55,4) and Convolutional coding (k=9,G1=561,G2=753)
- Turbo codes

The concatenated scheme is a very popular and proven coding scheme while the turbo coding is quite new but very powerful when dealing with AWGN.

Using the adaptive FEC property can adaptively control both codes to set the coding rate to the desired one (coding rates _, _).

11. Down Stream Block Diagram

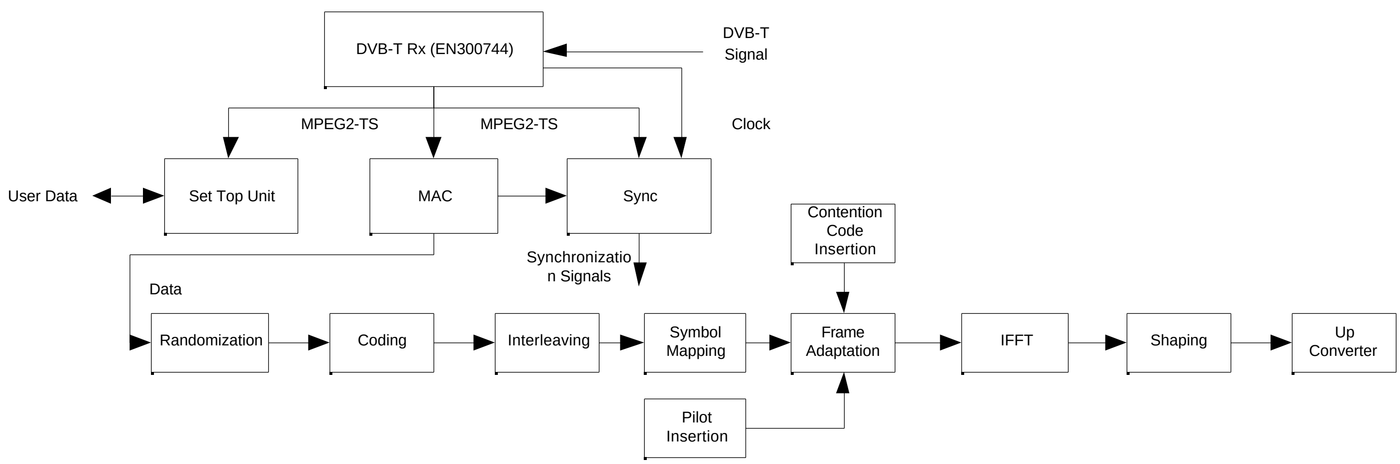
The following diagram represents an example for an FDD DVB-T Base station block diagram; this scheme represents all process of the Base Band:



In this diagram we can see that user's Data is extracted at the Base Station and transferred by a convergence layer to the MAC. The down stream which can be composed from MAC messages or other MPEG-2 source are multiplexed into the Down Stream, the MAC messages should only be encapsulated into MPEG-2 Transport Stream, by simple means of adaptation.

12. Up Stream Block Diagram

The following diagram represents an example for an FDD DVB-RCT user block diagram; this scheme represents all process of the Base Band:



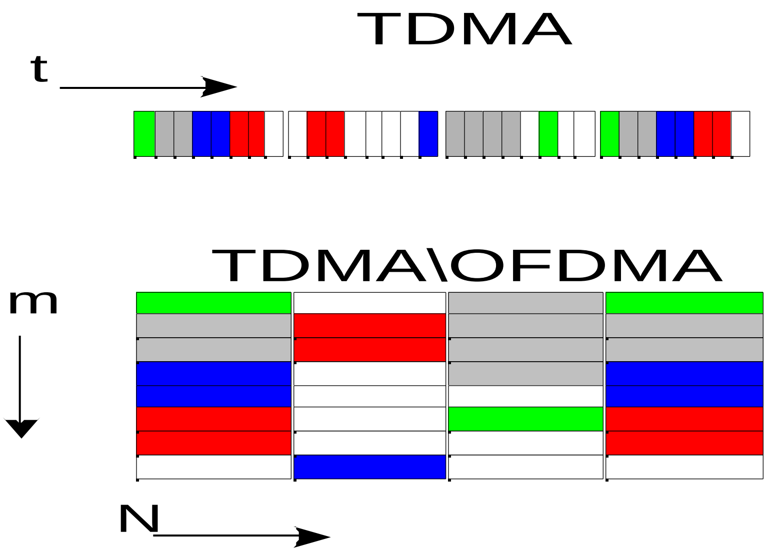
In this diagram we can notice that the user includes a simplified DVB-T receiver for the reception of the down stream. From the downs stream transmission parameters and clocks are extracted and used for the upstream creation.

13. Transmission Convergence

The 802.16.1 MAC protocol can be easily adapted to the proposed PHY by a convergence layer that will translate allocation of slots into TDMA\OFDMA approach (in the DVB-RCT similar convergence layer was developed in order to reuse the RCC MAC).

The OFDMA defines a slot as a pair {N,m} that represents a combination of an OFDM time symbol (N) and number of a sub-channel (m). the allocation that the MAC should allocate are exactly as for TDMA systems taking into account

that the slot number should be translate by the next formula (when using a 29 carrier Sub-Channels, and 54 working Sub-Channels per OFDM symbol): $t = 59 * N + m$
The TDMA\OFDMA can be presented as an extended TDMA approach in which several slots are transmitted in parallel as can be seen in the following diagram:



$$t = 59 * N + m$$

The given configuration will achieve slot granularity of ~18 bytes in QPSK with 1/2 code rate.

Several slots can be allocated to one user, what means that data can be transmitted in parallel resulting with flexibility that will be determined by the needed QoS restrictions.

14. System Throughput

For the Down stream the following table gives the Net data rates for the DVB-T system (in Mbit/s) for a 8MHz channel and a FDD duplexing:

Modulation	Bits per sub-carrier	Inner code rate	Net bit rate (Mbps) for different Guard intervals			
			1/4	1/8	1/16	1/32
QPSK	2	_	4.98	5.53	5.85	6.03
	2	2/3	6.64	7.37	7.81	8.04
	2	_	7.46	8.29	8.78	9.05
	2	5/6	8.29	9.22	9.76	10.05
	2	7/8	8.71	9.68	10.25	10.56
16-QAM	4	_	9.95	11.06	11.71	12.06
	4	2/3	13.27	14.75	15.61	16.09
	4	_	14.93	16.59	17.56	18.10
	4	5/6	16.59	18.43	19.52	20.11
	4	7/8	17.42	19.35	20.49	21.11
64-QAM	6	_	14.93	16.59	17.56	18.10
	6	2/3	19.91	22.12	23.42	24.13
	6	_	22.39	24.88	26.35	27.14
	6	5/6	24.88	27.65	29.27	30.16
	6	7/8	26.13	29.03	30.74	31.67

For the up stream the following table fives the Net data rates for the DVB-RCT system (in Mbit/s) for a 8MHz channel and a FDD duplexing:

Modulation	Bits per sub-carrier	Over all code rate	Net bit rate (Mbps) for different Guard intervals			
			1/4	1/8	1/16	1/32
QPSK	2	_	5.06	5.62	5.96	6.13
	2	_	7.58	8.43	8.93	9.2
16-QAM	4	_	10.12	11.24	10.9	12.26
	4	_	15.19	16.85	11.91	18.4
64-QAM	6	_	15.19	16.85	11.91	18.4
	6	_	22.76	25.27	26.79	27.6

The allocated bandwidth for the upstream and the down stream can be different in order to satisfy different scenarios or demands.
In order to compute bit rates for other channel bandwidth a good approximation will be to use this table as reference and multiplying it by the factor of: $NewBandwidth(MHz) / 8(MHz)$

Where the $NewBandwidth(MHz)$ parameter should be in MHz.

15. Better Combating the Channel

Due to long spreading time and Multipath, we propose bigger FFT structure (2048 points - although DVB-T has a 8192 points FFT also), this prolongs the transmission time and the guard time of the symbol.

I order to combat Multipath better a basic allocation of carriers (Sub-Channel) are spread all over the spectrum allocated, in order to achieve better frequency diversity.

The Guard Interval (GI), which is OFDM's main tool for combating Multipath is a constant ratio of a useful symbol, this GI is an overhead for the symbol time, which enables combating echoes. In order to calculate the GI for different FFT

Sizes, we shell take as an assumption a channel using a 12MHz bandwidth (72nsec per sample), using different GI for different FFT sizes we get the next results:

FFT size	GI in usec	GI value
512	10	_
1024	10	1/8
2048	10	1/16

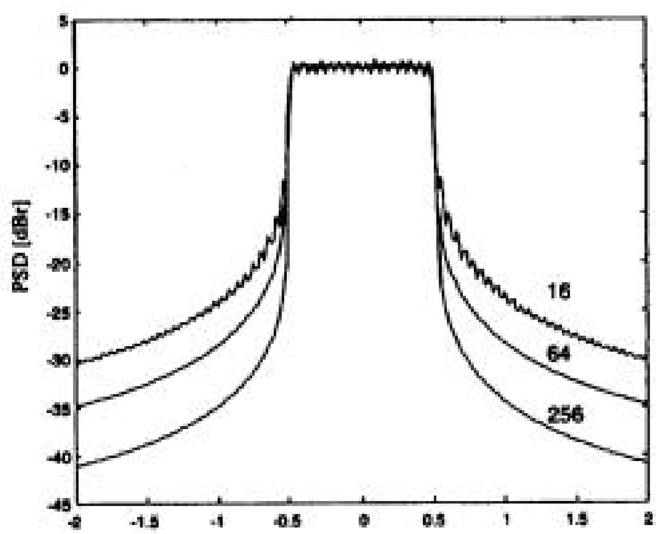
The delay spread calculated for the above case is for delay spread of 10usec, which are the reality of low frequencies. The system over head decreases as the number of FFT points increases, although the carrier spacing decreases. **For all cases the 2048-point FFT is the best solution and compromise**. The larger number of FFT points indicates that the GI is longer and gives better protection from Multipath and from echoes longer even from the GI. For an 8MHz channel protection of up to **50usec** can be given.

16. Phase Noise

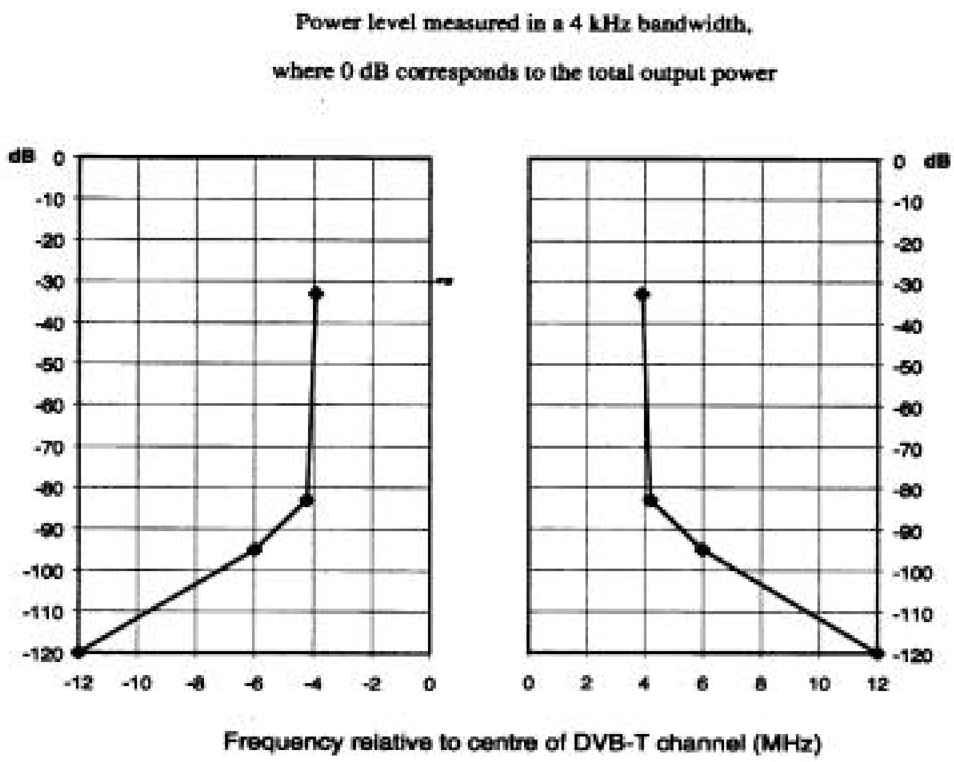
Phase noise for OFDM system has **almost the same restrictions** as single carrier systems. This has already been proven in regular and commercial DVB-T RF receivers (which are well known all over Europe and the world) and for ISDB-T RF receiver (which are OFDM systems in Japan). Regular DVB-T receivers are specified with phase noise of –70db/c at 1KHz and 10KHz, the DVB-T standard is defined with features that help combat the phase noise.

17. Better spectral shaping

The number of FFT points is responsible also for the spectral shaping of the signal. The more carriers used the better the spectral shaping and the out of band emission, for example 2048 points FFF has a **15dB better shaping** at half the bandwidth aside the end of the bandwidth then the 64 point FFT. An example of the shaping is taken from [1] and presented hereafter:



The figure illustrates the decay of the OFDM symbol when using different sizes of FFT as we can see 6dB reduction is achieved by quadrating the number of points therefore the difference between 64 points and 2048 points is about 15dB. The figure shown above is for rectangular windowing, the signal can be further perfected by adding windowing at the start and at the end of the signal, by that a DVB-T modulator can reach an 85dB decay 1/20 the frequency band away, as seen in the next figure:



18. Power Concentration

The OFDMA access in the downlink has many advantages. The biggest advantage beside the long symbol duration is the power concentration it enables. The power concentration is achieved due to power emission only on the Sub-Channels allocated. Therefore the energy of the user is transmitted only on selected carriers and not on the all-useable carries. This power concentration can add up to **18dBb** when comparing the power emitted on carrier when a user is allocated one Sub-Channel of 29 carriers or up to **26dB** for Sub-Channels of 4 carriers, to the power emitted when all Sub-Channels are allocated to one user.

This power concentration leads to several advantages:

- Better coverage
- Better channel availability
- Can use simpler and cheaper PA
- Can have better SNR for a transmitted signal
- Reach the distances specified for the system (better distances with the same EIRP).

19. System gain

The system gain shell be calculated for an 8MHz bandwidth, where we assume that the following table gives the SNR needed for different constellations to achieve a 10^{-11} BER for the down stream (for a 10^{-6} BER another 0.6-1dB can be subtracted, the figures where taken from the DVB-T standard using code rate of 1/2):

Modulation	SNR required
QPSK	2.1
16QAM	7.8
64QAM	13.4

The back off requirements for the down stream can be limited to 8dB with almost no degradation in the performance, for the up stream the back off depends upon the number of Sub-Channels allocated and varies between 5-8dB, with no dependence on the modulation used. Therefore for an ideal 0 dBW transmitter the expected power output is 22-25dBm and 2.5dB more for base power amplifier allowed emitting 4w. For the 8MHz channel the noise floor (taking into account an ideal LNA with 0 dB NF) is about –105dBm (-138dBm per carrier). Now taking into account that the power concentration for a 29 carriers Sub-Channel allocation is 18dB and for 4-carrier allocation it is 26 dB we achieve the next figures (worst case):

Modulation	RSG for the downstream [dB]	RSG for 29 carriers Sub-Channel in the up stream [dB]	RSG for 4 carriers Sub-Channel in the up stream [dB]
QPSK	127	143	151
16QAM	121	137	145
64QAM	115	131	139

The link budget for the upstream and downstream is the same due to the usage of more directive antennas in the users side and the extra margin needed for the uplink when using some of the frequencies in the upstream instead of all the frequency band. Any additional differences in the link budget could allow the usage of simpler and less powerful (therefore cheaper) PA at the user side.

20. Interference handling

When dealing with interference we should distinguish between two scenarios:

- Interferences from other systems using the same frequency band in the unlicensed band (like home appliances – microwave ovens etc.)
- Interference from other users inside the cell
- Interferences from neighboring cells/sectros, depending on the area covered the interferers could spread in Line of Sight (LOS) condition with a R^2 factor or a R^4 for a Non LOS conditions.

In order to combat these interferences we propose to use smart permutation on the Sub-Channel carrier selection, which will allow protection from neighboring interferers or Frequency blocking up to 30% of the spectrum, when the FEC is used smartly. The permutation includes the use of Reed-Solomon series in order to choose the carriers allocated to each Sub-Channels to get **better interference handling inside the cell.** Different series are also used between different cells, which give better treatment to **interference between cells** and a **better reuse factor**.

21. Coverage

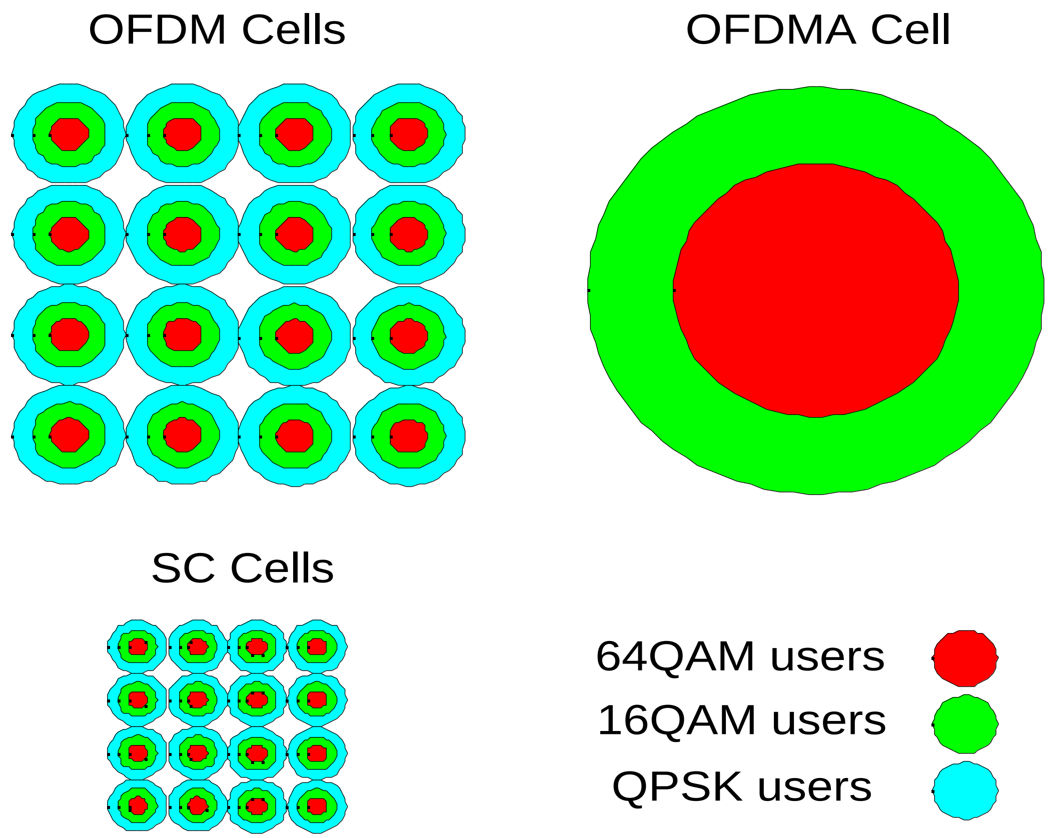
Due to section 19,20, some conclusions about the coverage of the cell arise. Due to the power concentration of the OFDMA, several advantages can be achieved:

- Cell radius increases – a **18dB or 26dB** advantage over a regular OFDM system (for a LOS propagation an increase by factors of 8 or 16, for NLOS condition and increase of 3 or 4 times the distance)
- Better penetration into houses and buildings, for simple indoor CPE (plug and play) using omni antennas.
- Over all throughput increases – users now can use higher order modulation due to better SNR
- Long symbol but small granularity enables better channel mitigation with small overhead and high efficiency.
- Repeaters can be added easily, signals from several places are translated at the receiver side just as an ordinary Multipath.

The next figures illustrate the differences between OFDM, OFDMA and Single Carrier (where appropriate).

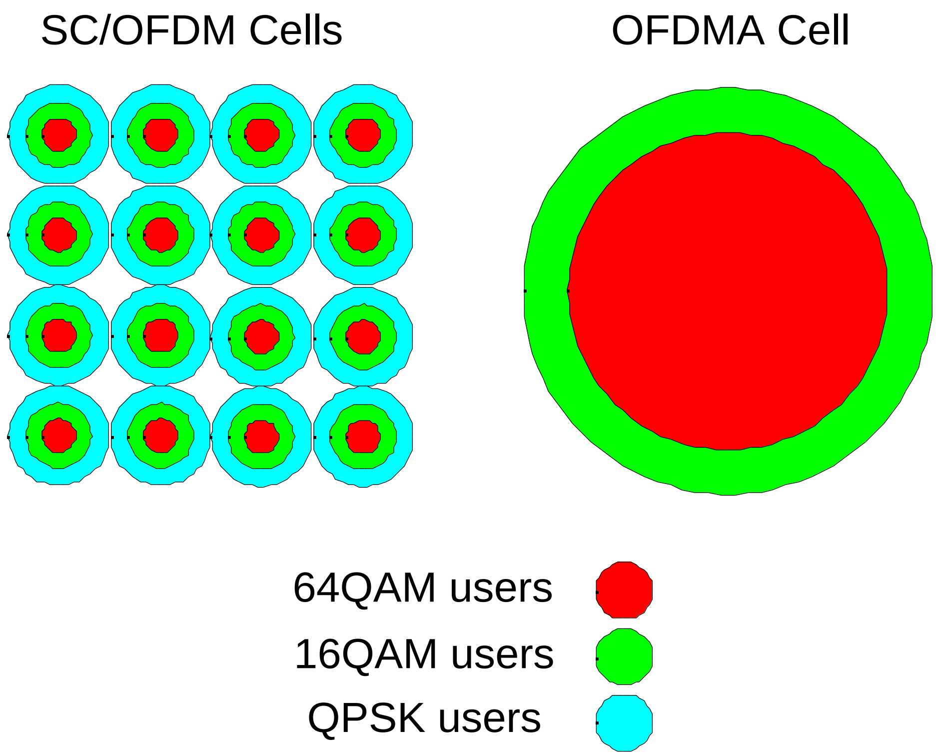
The first figure is the coverage when LOS/NLOS conditions are involved where for NLOS the OFDM systems are much superior to those of the SC, and the OFDMA one performs better both in range and in capacity due to the power concentration. The power concentration gives us 3 to 4 times the range in LOS conditions and 50% to 100% more for NLOS conditions.

LOS/NLOS Conditions - Coverage limited



The second figure ideals with the capacity issue of cells where capacity limitations are the main problem and the OFDMA system performs better due to the use of higher constellations.

Capcity limited cell structure



22. Additional possible features

For even better coverage and throughput, mechanisms like antenna diversity at the Base station and at user side (where it is appropriate) are very effective against channel fading and Multipath. Means as space-time coding code be incorporated in an OFDM/OFDMA system in a very efficient way.

Directional antennas at the user side are also a feature that can be implemented for better coverage and interference rejection.

23. Evaluation table

The following table contains evaluation of the evaluation table published in IEEE802.16.3-00/14, the evaluation results from the proposed PHY:

#	Criteria	Proposed System
1	Meets system requirements	The proposed system gives solution to every demand of the FRD and the PAR, including broadband links of more then 10Mbit/s and distances of up to 50Km.

2	Channel Spectrum Efficiency	The full table of the system throughput is given in section 14. to summarize the system supports adaptive modulation of QPSK, 16QAM and 64QAM and different coding rates (differ in the uplink and downlink), this will enable the system to gain the highest throughput possible fro a certain scenario. The maximum Net throughput for the down stream is 32Mbps and for the upstream 25Mbps (for a 8MHz channel). The channel bandwidths proposed for the system are 1.5,1.75,3,3.5,6,7,8,12,14,25MHz. The OFDMA access enables the adaptation of the bandwidth per user, giving another dimension to user allocation flexibility and trade off between distance and peak throughput per user.
3	Simplicity of implementation	Today OFDM technology is well known, and the implementation of FFT components has become negligible. The OFDM/OFDMA access does not have effect on the MAC layer due to simple convergence layer; therefore the access system is independent of the MAC. The DVB-T which is proposed for the down stream is a well known technology, where today there are about 8 ASIC manufacturers producing chips. The DVB-RCT, which is based on the DVB-T receiver chip, will be manufactured after its standardization by several large ASIC manufactures therefore achieving a single system chip.
4	SS Cost optimization	The DVB-T which is proposed for the down stream is a well known technology, where today ASIC manufacturers produces these chips. The RF ends for the subscriber unit can be built with off the shelf RF ends or components.
5	BS Cost optimization	The large production of Base station will enable cost reduction and simple interfaces to the base station enables it's cost reduction.
6	Spectrum Resource Flexibility	The system proposed can be very easily adapted to support different bandwidths by just adjusting the system clocks. This will enable the worldwide use of such a system in different world regions. The system can be planned to FDD or TDD operation with an excellent spectral mask allowing very sharp spectral mask and less out of band interference.
7	System Service Flexibility	The PHY is planned in such a way that the convergence layer between the PHY and MAC will enable the transparent usage of the PHY. The system is planned for great flexibility and can answer the required and potential future services, while supplying high spectral efficiency system.
8	Protocol Interfacing Complexity	The interfacing to upper layer is done by the usage of a convergence layer. The delay of the PHY system is about 0.75-1msec for the down stream and 1.5msec for the up stream. These short delays will enable the usage of all services currently defined in the system
9	Reference System Gain	High reference system gain for the downstream can be reached due to good coding gain. Excellent coding gain is achieved for the upstream due to power concentration, which can give up to 18,26dB additional gain. Furthermore the adaptive modulation can trade off another 20dB, and therefore adjust the performance of the cell to the optimum.

10	Robustness to interference	The up stream is planned is such a way so that the spectral shape of the signal is very sharp for the out of band emission therefore minimizing the outer cell interference, also planning the Sub-Channel allocation differently between neighboring cells gives maximum robustness and statistically spreading interference between cells. For intra cell interference the Sub-Channels are allocated by special permutation that minimizes the neighboring carriers between two channels and statistically spreading the interference inside the cell. Other features that protect the signal is the frequency diversity of the system with an ECC planned to handle 25-30% of the frequency blocked using also time interleaving of users signal. All the above brings us to an optimal system and a very good reuse. Robustness to interference is also supported by the adaptive adaptation of bandwidth, modulation and coding, as well as additional features that can be implemented as: · Directional antennas where it is appropriate (to reduce interference to other users) · Directional antennas at the user side · Diversity antennas at the BS and at the SS (where appropriate). · Space/Time Coding are fitted very well to OFDM/OFDMA technology
11	Robustness to Channel Impairments	The OFDM is well known for its well-proven qualities dealing with tough wireless environments. The estimation that can be achieved within one OFDM/OFDMA symbol because of fading is about 40dB, giving excellent recovery opportunity, the OFDM/OFDMA technique is also very powerful for the location and nulling of regional interference therefore helping the decoders achieve better performances and treating up to 30% of channel frequency blocking or fading. The excellent link budget and adaptively of each user can handle large amounts of fading due to rain, flat fade, Foliage etc. other features as: · Diversity antennas at the BS and at the SS (where appropriate). · Space/Time Coding · Time Diversity of the signal · Adaptively of Code and Modulation Are also combined to get the maximum out of the channel.
12	Robustness to radio impairments	The OFDM sensitivity to phase noise is almost the same as for single carrier systems, today the same RF ends are used for OFDM and Single Carrier systems, and the defined DVB-T has inherent features to help and estimate the phase noise. Group Delay of filters is solved for OFDM as simple channel impairments and is estimated along with other wireless channel effects. Channel estimation solves all the problems the RF ends introduces. Power amplifiers Non-Linearity can be solved in the digital level although it has small effect in OFDM systems [1],[2].

24. Intellectual Property

Intellectual Property owned by RunCom Technologies LTD. may be required to implement the proposed PHY specification. The authors are not aware of any conditions under which RunCom Technologies LTD. would be unwilling to license Intellectual Property as outlined by the IEEE-SA Standards Board Bylaws, if the proposed specification will be adopted.

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