Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**802.16.3 Air Interface: An Outline PHY Proposal**
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Re:	802.16.3 Call for Contribution on Initial PHY Proposals (Document No. IEEE 802.16.3-00/14)
Abstract	The purpose of this contribution is to present an outline description of a proposed PHY for 802.16 TG3. Key characteristics of this proposal include (1) OFDM, (2) adaptive multibeam base station, and (3) TDD. In Section 1 discusses some background and motivation for these characteristics. Section 2 focuses on the benefits of using adaptive multibeam technique at the base station (not at the subscriber station). Section 3 discusses compliance against the evaluation criteria listed in the Call for Contribution.
Purpose	To summarize the key characteristics of an outline PHY proposal as input to the TG3 evaluation process.
Notice	
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Patent Policy and Procedures	

802.16.3 Air Interface: An Outline PHY Proposal

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1 Introduction

The TG3 PHY proposal outlined in this contribution contains the following key characteristics:

- OFDM as the modulation scheme to provide robust link performance in multipath and non- and near-line-of-sight (NLOS) environment
- TDD as the duplexing scheme to take advantage of the path reciprocity and the flexibility to support upstream/downstream asymmetry
- Multibeam base station (BS) using adaptive beam forming techniques to achieve higher spectral efficiency and better coverage
- No beam forming is required at the subscriber station (SS) to keep the cost low.

These characteristics are driven by the TG3 frequency bands (small allocations, high spectral efficiency requirement), propagation characteristics (NLOS and rich multipath environment), and the targeted markets (residential and small businesses, which require low-cost subscriber stations and large number of them per base station).

The main motivation for the above mentioned characteristics are as follows:

- TG3 air interface must be able to deal with non line-of-sight propagation paths and multipath fading. OFDM has proven to be a robust method in such an environment and should play an important role in the TG3 air interface.
- OFDM typically assumes comprehensive digital processing architecture compared to other more traditional approaches to support FFT processing. Taking advantage of the digital hardware and with modest additional processing power, one can add adaptive multibeam capability to the base station, and reap the benefits dramatically increased capacity and coverage.
- While adaptive multibeam can be used with either FDD or TDD, an important synergy exists with TDD. In TDD, there is a path-reciprocity between uplink and downlink, so that adaptation parameters in one direction can be derived from the adaptation parameters in the other direction. The upshot is that it is sufficient to perform adaptation only at the BS and not at the SS. Therefore, adaptive multibeam processing does not increase the cost of the SS.

2 Adaptive Multibeam Base Station

It is important to understand that an adaptive multibeam BS is very different from a BS using sectorized antenna. Figure 1 illustrates a sectorized antenna system. The radiation pattern of a sectorized antenna is fixed. The sectors are designed according to the coverage and capacity requirements, and a SS is assigned to an appropriate sector based mainly on its azimuth location. Each sector can be considered an independent domain in which the base station broadcasts to all SS within that sector.

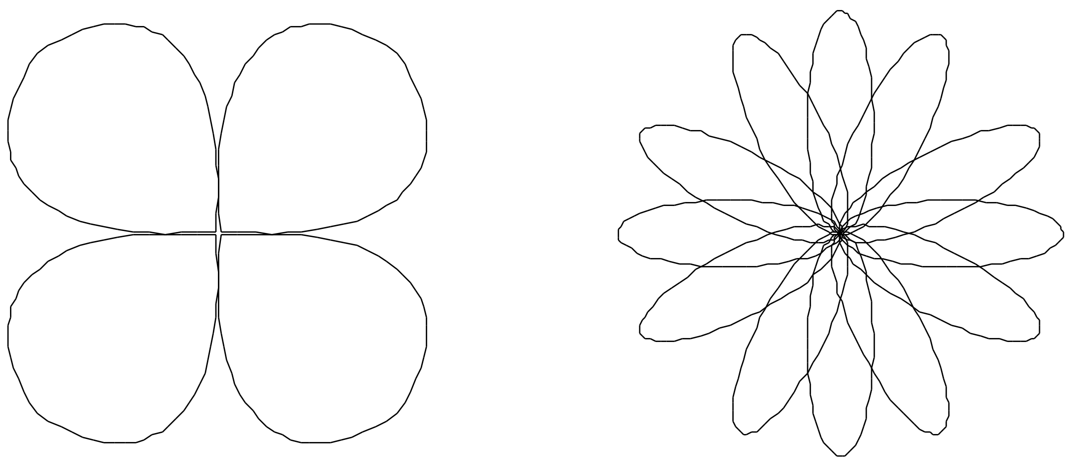

Figure 1. Sectorized antennas.

An antenna array can be used to create the sectorized beam pattern. In this case, one can also take advantage of the diversity gain that comes with such a system to help mitigate multipath fading, assuming sufficient spacing exists between antenna elements. Two popular diversity methods are switched-beam or maximum ratio combining. The switched-beam system dynamically reassigns a SS to the best beam at the moment. The maximum ratio combining system takes signals received by multiple antenna elements and combines them to produce the maximum signal-to-noise ratio (SNR) at the output.

Adaptive multibeam systems take it one step further. In this case, the beam pattern is no longer fixed. Rather, when the base station needs to communicate to a SS, a beam is created just for that session. This is accomplished by dynamically adjusting the phase and amplitude of signals received and transmitted by all antenna elements, such that their superposition produces the desired beam pattern. In essence, a sector is dynamically created for a single SS. Adaptive multibeam systems have many advantages over the sectorized and diversity systems, as discussed below.

- Increase in SNR
  The beam width of sectorized antenna is constrained by the need to cover the whole cell. For instance, if there are four sectors in a cell, then the beam width must be larger than 90 degrees. Of course, the more sectors there are, the narrower the beam widths. But practical considerations often limit how far one can go in this direction. Moreover, as we have little control over the location of a SS, it is more often than not that the SS will not be at the antenna boresight, and gain is further reduced. In an adaptive multibeam system, because a beam is formed for a single SS, the beam width is no longer constrained by the cell coverage requirement, and much narrower beams can be formed in the direction of the SS, leading to higher gains and improved SNR. Figure 2 illustrates this comparison.

  The increased SNR can be used to increase the link availability or range of coverage. Two to three times increase of cell radius can be obtained with practicable base station array size. It also leads to improved coverage within a cell. Because of shadowing and multipath fading effects, there are typically many “holes” within a cell where the SNR is insufficient to close the link. Increased SNR obviously helps to shrink these holes.

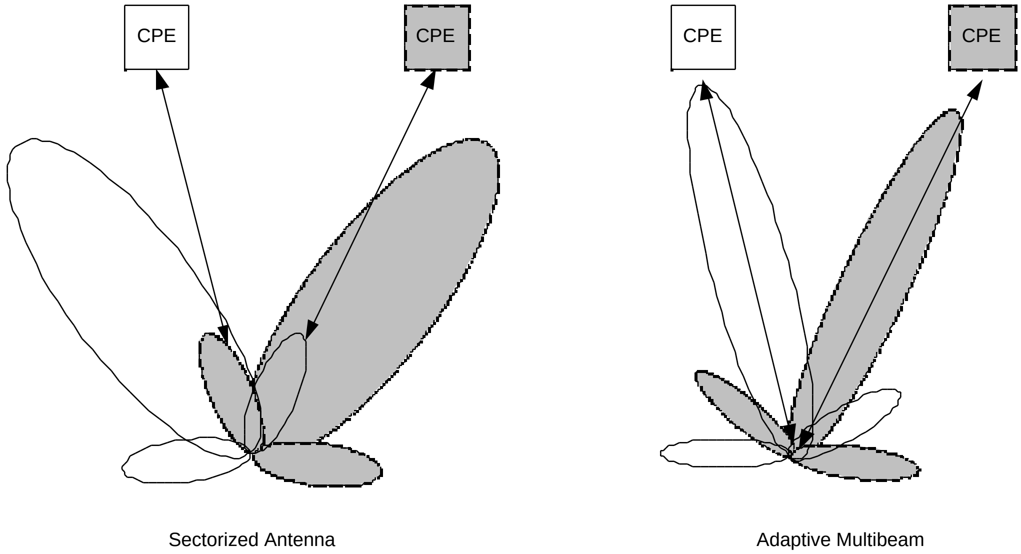

Figure 2. Comparisons between sectorized and adaptive multibeam systems.

- Additional Increase in SINR
  Another big advantage of adaptive multibeam system is its simultaneous ability to steer nulls toward an interfering source, thus suppressing the interference and further increase the signal to interference plus noise ratio (SINR). This is also illustrated in Figure 2. The increased SINR is even more important than SNR improvement, because multi-cell deployments are typically interference limited. Dramatic capacity increase can be achieved as a result of SINR improvement.

- Spatial-Division Multiple Access (SDMA)
  The interference suppression capability of the adaptive multibeam system not only allows one to increase the frequency reuse between cells, but also permit intra-cell frequency reuse, also known as SDMA. A dramatic increase in spectral efficiency can be achieved, at lease five to ten times compared to existing fixed wireless systems. High spectral efficiency is of paramount importance for TG3. As the frequency bands between 2 to 11 GHz tend to be small chunks compared to TG1, spectral efficiency has a strong impact the economical viability of a technology.

- Deployment Flexibility
  As a system is rolled out, it is natural to desire more range than capacity in the beginning with as few base stations as possible. As the number of SS increases, more and more capacity can be added. This desire is difficult to satisfy with sectorized antennas, because fewer sectors necessarily means wider beam width and thus smaller range. The adaptive multibeam system, on the other hand, fits this desire very well, since its beam width is not constrained by the number of sectors.

- RF and Digital Hardware Tradeoff
  Obviously, adaptive multibeam systems require additional processing, mostly due to the digital signal processing required to perform adaptive beam forming. However, the increase is partially offset by the reduced RF hardware requirements. For example, an array of ten elements each with a 1 W power amplifier theoretically can produce as much power as a single element driven by 100 W power amplifier. In addition, the digital signal processing also leads to relaxed tolerance of the RF components.

3 Outline Evaluation Against TG3 PHY Characteristics

1. Meets system requirements
   The PHY outline discussed here can meet all the mandatory and optional requirements of the TG3 FRD. First, it should be clear that no requirements in the FRD are excluded or degraded by using OFDM, adaptive multibeam, and TDD. Second, these characteristics in fact are selected specifically to meet the fundamental requirements in the FRD, such as NLOS and multipath, spectrum efficiency, and SS cost.

2. Channel spectrum efficiency
   The PHY outline discussed here can support a variety of modulation and coding schemes similar to traditional systems. It is essentially "agnostic" in this respect. However, the ability to support SDMA can increase the spectrum efficiency and capacity by an order of magnitude even with the same modulation and coding methods.

3. Simplicity of implementation
   The PHY outline discussed here uses well established OFDM, TDD, and adaptive antenna techniques, but keeps most of the complexity at the BS in order to minimize SS equipment, installation, and deployment costs. At the BS, the complexity is mostly confined to DSP software using industry standard processor and chipsets. Moreover, the ability to perform digital adaptation yields relaxed requirements on RF equipment, hence reducing their complexity and cost.

4. SS cost optimization
   The use of OFDM, TDD, and IP-based optimization minimizes the complexity and cost of the SS equipment. Adaptive multibeam is done at the BS only, which does not affect the cost of SS.

5. BS cost optimization
   By confining the system complexity primarily to software in the BS, and by using TDD, the initial BS configuration is kept simple and economical. As pointed out in Section 2, adaptive multibeam essentially decouples the range and capacity requirements, so that initially smaller BS can be installed to provide the necessary range of coverage, with the ability to increase capacity as necessary by adding processing modules.

6. Spectrum resource flexibility
   OFDM and adaptive multibeam can operate in conventional FDD paired bands as well as conventional single TDD blocks, though TDD is preferred. Because of the high spectrum efficiency achievable by using adaptive multibeam and SDMA, even small spectrum allocations (5-10 MHz) can be used to provide viable services.

7. System service flexibility
   The PHY outline discussed here is transparent to services required by the FRD. The eventual PHY proposal will be optimized for IP-based protocols capable of supporting all the mandatory and optional FRD services.

8. Protocol interfacing complexity
   The PHY outline discussed here can support any multiple access schemes consistent with SDMA, including TDMA and FDMA. The digital adaptation capability will simplify some network management protocols like power control.

9. Reference system gain
   The use of OFDM helps mitigate multipath and NLOS channel impairments, thus reducing the fade margin necessary to assure a specified link availability and reliability performance. In addition, as pointed out in Section 2, adaptive multibeam provides orders of magnitude improvement in SNR and SINR compared to a sectorized antenna approach. Two to three times cell radius and five to ten times spectrum efficiency can be obtained using this approach.

10. Robustness to interference
    The adaptive multibeam BS is capable of simultaneously steering a beam toward the desired SS and nulls toward interfering sources, and is therefore very robust to interference, both internal and external.

11. Robustness to channel impairments
    The use of OFDM has proven to be effective in mitigating multipath and other near/non LOS channel impairments. The use of adaptive multibeam provides additional improvement due to the significantly enhanced SNR that is achievable.

12. Robustness to radio
    As pointed out in Section 2, digital adaptation capability allows for relaxed tolerance in RF equipment and thus enhances robustness.