Smart Antennas in WiMax system

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Introduction:

Similar to all the wireless communications solutions, the WiMax solution contains two basic categories of antennas: antennas for base stations and antennas for the terminals.

For the base stations, using the state of the art technology, today it is possible to apply two new groups of base station antennas solutions: adaptive antennas, and MIMO antennas (multi-input-multi-output).

For the users terminals, the antennas solutions are divided to two sections according to the level of mobility of the end user: For fixed terminal, and mobile terminal, such as in a car, bus, train, etc.

Figure 1 describes the terminal antenna solution for fix and mobile applications.

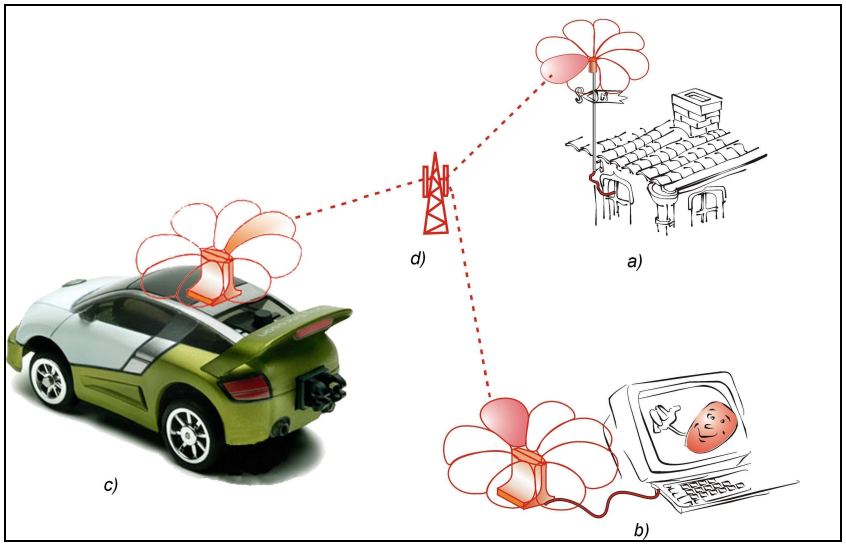


Fig.1 WIMAX user terminal antenna system
Basic antenna types.
a: fixed terminal outdoor antenna b: fixed terminal indoor antenna
c: mobile terminal antenna d: Base station antenna

Types of antennas solutions

a. **Switched beams antenna**: A set of radiators with fix radiation patterns and control for selecting dynamically the best beam. For every given user the base station and / or the terminal chooses the best beam, by getting the maximum gain.

b. Scanning beam antennas: Antenna array with phase shifters and attenuators that are managed by the antenna processor. The processor is controlling the beam to the best direction. In this case, we are getting smooth scanning which gives essential advantages by accurate pointing to the user or the base station. Such an antennas makes use of various mathematical beam-forming methods for creation an optimum beam: maximum gain in the direction of the user and minimum gain in the direction of an interference signal.

The Main problem

The main problem in the wireless communication is to get reliable coverage of space including dead spots. As it always happens, data rate transmission for Internet connection, audio and video information is not sufficient. There are two ways to increase the speed of data transmission in wireless networks:

a. Improvement of data coding efficiency which decreases the quantity of repeated data retransmission that usually occurs due to weak signal reception. This option, reduces the bandwidth due the increasing of the error correcting codes bandwidth consumption

b. Improvement of the quality of signal, which is possible by increasing the transmitter power or improvement of the receiver sensitivity. This option requires adding new power amplifiers in the transmitter and low noise amplifiers in the receiver. This option increases the systems costs and contradicts standard requirements.

So, it seems to be that both options don’t give the optimized solution. But there is another, more effective and inexpensive way for improvement of signal quality.

It’s possible to design antenna, which transfers the most of the power in a specific required direction. Such antennas can also receive signals from that direction with better quality than all other directions. Now, we shall introduce several directional antennas which automatically choose the optimal direction for getting the best quality. This device is defined as adaptive antenna. Traditional antennas, such as "dipole" or "patch", radiates energy equally in a horizontal plane that means they have omni directional radiation pattern.

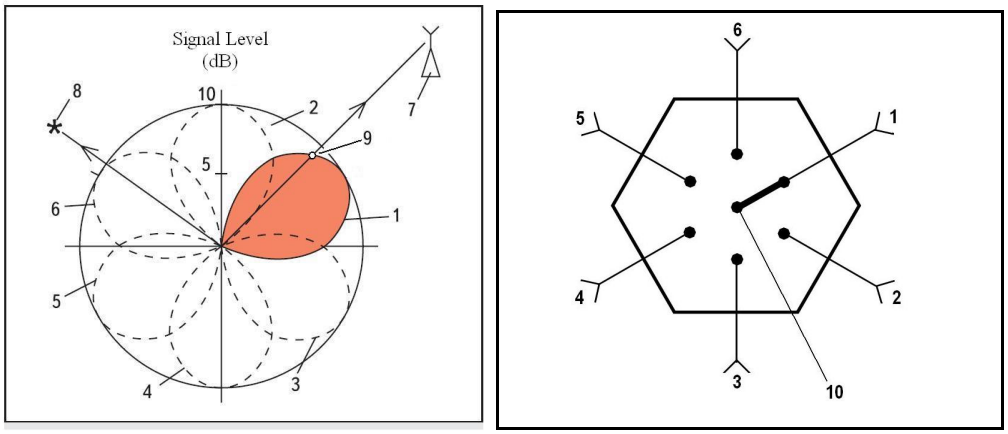
Switched multi-beam antennas [1] may have 25 beams in a horizontal plane, with 7dBi peak gain for each one, so the signal is three times stronger, than with a standard dipole antenna with 2dBi gain. Tests for comparison between the regular Omni antenna and the multi-beam antennas were as follows: high throughput: 20-30 Mbit/s; average throughput: 10-20 Mbit/s; low throughput: 0-10 Mbit/s.

Using statistical measurements in each option (at 95 % of reliability) the terminal with the multibeam antenna gave 6.7 Mbit/s more throughput in comparison with terminal equipped with monopole on average throughput and 90 % throughput higher in areas with a small radio signal.

1. User Terminal solutions

Fixed terminal - self installation antennas

It is possible to apply the multi-beam antenna with 7-10 dBi gain for fixed outdoor terminals. Such system provides higher signal from when pointed to the base station, and reduces interference signal from all other directions. The scheme of construction of such antenna and its radiation pattern are displayed fig.2a and fig.2b.



a) b)

Fig 2. Multi-beam antenna radiation patterns. a) antenna radiation pattern b) antenna construction 1 –active radiator, 2-6 non active radiators, 7 – base station,8 – Interference source, 9 – level of signal, 10 – switch

The multi-beam antenna improves data transmission throughput. The important feature of multibeam antenna is that it is automatically directed to toward of base station direction, or to the strongest reflection direction if there is no line of sight in a multi-path propagation conditions. This mode of operation called "auto search" or "self installation antenna"

In the market we can be find six and eight beam antennas for indoor usage working in a frequency range of 2.5 GHz and 3.5 GHz. An example of such antenna from a source [2] is displayed on Fig.3.

Fig.3 Multi-beam switched antenna (3.5GHz) from MPA ltd.

The gain of that type of antennas is about 10dBi in the direction of the base station and 15-20 dB suppression of interfering signals from all other directions. Such antenna allows to increase throughput of a radio channel and have robust communication despite continuous changes in radio wave propagation conditions. The antenna continuously makes an automatic search of the best beam direction. So, if a change of propagation conditions occurs (terminal position change, furniture and people movement, etc.). The antenna will give the maximal gain. Figure 4 shows an indoor multi-beam antenna.

Fig.4 Indoor multi-beam switched antenna 3.5GHz

Mobile terminals antennas

The possibility of "auto search" and continuous beam tracking are extremely important for other class of the equipment - mobile user's terminals. In such a case, making use of an omni directional antenna, gives very poor quality of signal and as a result, communication throughput is very low. In this case additional external multibeam antenna with 10 dBi gain, as shown in fig.5 will increases significantly the signal quality, improves quality of communication and data transmission throughput.

Fig.5 Installed mobile terminal antenna by MPA ltd

It is necessary to emphasize, that in conditions of urban environment, communication with mobile terminals occurs, mainly, without line of sight to base station, and in such complex conditions, the advantages of adaptive antennas are very significant.

Figure 6 shows optional configuration for antennas that covers 360 degrees.

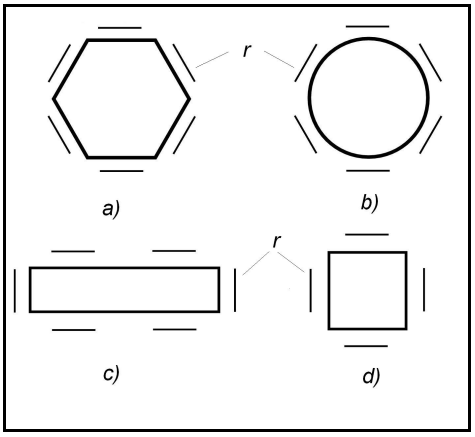


Fig.6 Optional configurations for 360 degrees covering antennas
a - six-coal, b – round, c – rectangular, d – square
r- radiator.

2 Base stations Solutions.

Using the newest algorithms, adaptive antenna system allows finding and efficiently tracing signals from user terminals with minimal interference and best quality. Inputs of antenna elements are incorporated in a beam forming circuit which includes phase shifters and attenuators. For comparison, if usual antenna with covering width of 120 degrees with two elements gives 15 dBi

gain, the adaptive antenna with 8 elements has the maximal gain of 24 dBi. For example, the Alcatel's base station antenna, two and four element antennas are used. Due to beam forming circuits and use of adaptive algorithms, throughput of the channel increased by 40 % and interference influence is reduced by 80 % [3].

MIMO solutions

Additional improvement in communication quality used by Alcatel's equipment is achieved by MIMO system. This technology is used in common with a smart antenna, and provides additional possibilities.

MIMO solution is a time - space coding which creates an advantage due to division of the dataflow transmission through two or more antennas on different spatial ways, switching to the best direction, or working simultaneously.

One of the main problems of this solution is the high price for the user terminal, the need for additional space and additional energy of power supply [4].

Comparison of different type of smart antenna

Antenna Type	**Switching multi-beam antenna**	**Adaptive antenna with beam forming circuits**	**MIMO**
Advantages	Simple implementation Low cost	High throughput and interference suppression Perfect for use in non line of sight Environment	High data speed Perfect for use in multi-path propagation environment
Disadvantages	Limitation in beam forming possibilities Only one radiating element in required direction	Average complexity High price Have to be at least one radiating element in required direction	High complexity High price In development stage

3 Channel efficiency due to adaptive antenna usage

The main issue in wireless communication is a channel spectral efficiency. Adaptive antennas in WiMax wireless networks not only raise those parameters but also dramatically increase coverage area.

Stanford University research [5] shows that spectral efficiency can gain additional 2.5 bit/sec/Hz to cell and the data throughput to cell area 0.8 bit/sec/Hz/mile^2.By usages of adaptive antennas on both base stations and user terminals can achieve 3 – 10 times better spectral efficiency than with regular antenna.

Conclusion

The adaptive antenna technology uses antenna arrays integrated with modulators and digital signal processors on base station as well as on user terminal in order to improve following wireless system parameters: coverage area enlargement, channel capacity, system throughput.

The advantages of such antennas:

-signal to noise ratio grow due to coherent signal summation;

-spatial diversity of array elements help to reduce fading influence on a system performance;

-Interference suppression due to adaptive beam forming which uses the array elements to form;

-radiation pattern with maximum in desired direction and minimums in an interferences direction;

- spatial channel multiplexing.

Reference:

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2. www.mpa.co.il
3. Flavio Boano, “Alcatel WiMax” , *Enhanced Radio Features, CAMAD 2006 Trento.*
4. Dan O’Shea,”MIMO on the March”, Apr.24, 2006
5. Khurram Shekh, David Gesbert, Dhananjay Gore and Arogyaswami Paulraj, ”Smart antennas for broadband wireless access networks”, *IEEE Communication Magazine, Nov*. 1999.