ALATA: a straightforward long-term policy towards minimal electromagnetic exposure levels in society

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Abstract: A new principle to tackle the problem of how to deal with rising electromagnetic radiation levels in society is introduced and worked out at the conceptual level: the ALATA principle, meaning ***As Low As Technically Achievable***. The principle takes into account the democratic wish of the average citizen to communicate wirelessly and combines it with the technical performance of state-of-the-art telecommunication technology. In this way it is able to give a clear answer to the question of what levels are still acceptable in society. It completely avoids the never-ending difficult debate on what levels have to be considered as "safe" and which ones as "dangerous". Further, it clearly points out which measures need to be taken in order to further reduce the levels in the future. Only real conceptual and strategic measures are discussed for which political involvement and decisions are crucial. The ALATA principle could form a solid foundation on which policy makers base decisions related to the electromagnetic exposure issue.

KEYWORDS: Electromagnetic exposure, health hazard, telecommunications, precautionary principle.

1. Introduction

The debate in society on the possible hazardousness of electromagnetic radiation, further called EM radiation, is a hot issue. Almost every day new articles appear in newspapers on the possible negative effects of EM radiation, in most cases based on isolated scientific studies. In some cases these messages are picked up by radio and TV, leading to mystifying discussions between the parties "pro" and the pressure groups "contra". This has led to a situation where it is extremely hard for the average citizen to make his or her own proper judgment on the issue. It is far beyond the scope of this paper to give an overview on the possible effects of EM radiation on biological tissue, animals, and human beings, but for the interested reader a good starting point is [1].

One of the most important basic questions is: which radiation levels are still acceptable and which are not? Since state-of-the-art biological and medical science is still unable to give a clear answer to this question, politicians and policy makers have a hard time making the proper decisions. Whatever level is decided, they are always criticized, in many cases both by the pressure groups (the level is too high) and the telecommunication industry (the level is too low). In Europe this has lead to a multitude of norms and scattered legislation on the issue. Some countries follow the international trend (ICNIRP, WHO), other countries have much more stringent rules (for example Belgium). This wide range of levels

allowed in the different countries and regions has lead to even more confusion amongst European citizens.

Starting from a different paradigm, this paper tries to break through the normal ways of dealing with the problem. First the basic undeniable facts are listed. Then, based on these facts, a line of reasoning is built that clearly points out which levels are best adopted at the moment. The foundations of the principle are twofold: first, the democratic wish of the population to use wireless communications in daily life, and second, the fact that technological progress allows to put more and more stringent regulations in place, leading to the concept of "dynamic regulation".

2. Basic facts

It is a fact that in the last few decades EM radiation levels have risen enormously. In Europe, the natural background noise level at 10 MHz for example is ca. 1 μV/m per kHz bandwidth [2]. Present day mobile communication base stations are easily capable of producing several V/m within their operating bandwidth in closeby accessible public spaces, which is many orders of magnitude larger.

It is a fact that wireless communications is still on the rise. More and more applications join the wireless paradigm, yielding more and more radiating antennas appearing in society. In Table 1 several "popular" radiation sources are tabled, together with their most important technical characteristics and typical exposure levels. It is a fact that to the average the most "polluting" sources in society at large are the cellular mobile communication systems. Measurements performed over the last 10 years in Belgium within the context of the author's research have clearly pointed that out [3], [4]. Concerning exposure, the main systems to consider over the years were/are GSM, 3G, and 4G systems. Even the Wi-Fi systems providing wireless internet, although also ubiquus in society, in most cases contribute far less to the total exposure level.

Source	Frequency (GHz)	Power (W)	Distance (m)	Typical exposure (W/m^2)	Typical exposure (V/m)
Radio/TV	kHz – MHz	up to 100 kW	1000	0.016	2.46
GSM BS	0.9, 1.8	20 – 100	10 100	3.2 0.032	34.7 3.47
GSM handset	0.9, 1.8	0.02 – 2 (1/8 time)	0.01 – 0.02 1	2 – 200 0.0002 - 0.02	27.5 – 275 0.027 - 0.27
DECT (phone)	1.9	0.25 peak	1	0.02	2.75
WLAN, WIFI (internet)	2.4	0.1 peak	1 10	0.008 0.00008	1.74 0.17
Bluetooth	2.4	0.001 – 0.01	0.01 – 0.02	0.8 – 8	17.4 – 54.9
UMTS handset	0.85, 1.7, 1.9, 2.1	max. 0.125 – 0.25	0.01 – 0.02	max. 12.5 – 25	68.7 – 97.1
Sun	Broad spectrum ionizing!			1400	726.5

It is a fact that to date the real implications of the exposure of large populations to these higher unnatural EM radiation levels are unknown. Literally thousands and thousands of scientific articles have been published on this issue in biological and medical scientific journals. Some of them suggest effects,

in most cases negative, i.e. hazardous, sometimes positive, i.e. therapeutic [5]. A discussion on this is far beyond the scope of this paper. However, to the knowledge of the author, none of the papers published in literature delivers a final, undeniable, and uncontestable proof of hazardous effects on the very complex system that is the human body. As far as the author knows, the only consensus in the scientific community concerns so-called Extremely Low Frequencies (ELF), a frequency range not used for wireless communications. It is the statistical relation between the higher occurrence of leukemia in small children and higher ELF electromagnetic fields, see for example [6]. Also a statistical relation with Alzheimer's disease is under investigation.

It is a fact that no drastic (hazardous) effects are seen in society in the short and medium term. In the author's opinion, it can be safely said that the short and medium term effects of telecom related electromagnetic exposure as seen in nowadays society on the average citizen are probably extremely small to negligible.

It is also a fact, however, that the largest and most crucial unknown in the exposure debate is the long term effect. What will this EM radiation exposure do over a period of 50 – 60 years? This long term effect is impossible to know or even assess at this moment. The technology and its users have not been around long enough. One can compare with smoking. People who smoke have a higher risk of getting cancer, but not immediately. The median age of lung cancer diagnosis is 70 years for both men and women. Most cancers occur thus after 40 – 50 years of smoking. Should we fear something similar here?

It is a fact that wireless technology is very well-accepted by the average citizen. The number of subscribers is constantly increasing see Fig. 1. In Belgium for example, the penetration rate of mobile phones (number of subscribers over number of inhabitants) in 2013 was 114 %. Even many hard liners in the pressure groups dealing with the issue have a mobile phone. Wireless technology has become widespread and is here to stay. It is unfeasible to imagine that measures can be taken that would fundamentally impede the use of wireless technology. On the contrary, where the rise of mobile communication is really threatened, too tough legislation is under scrutiny [7].

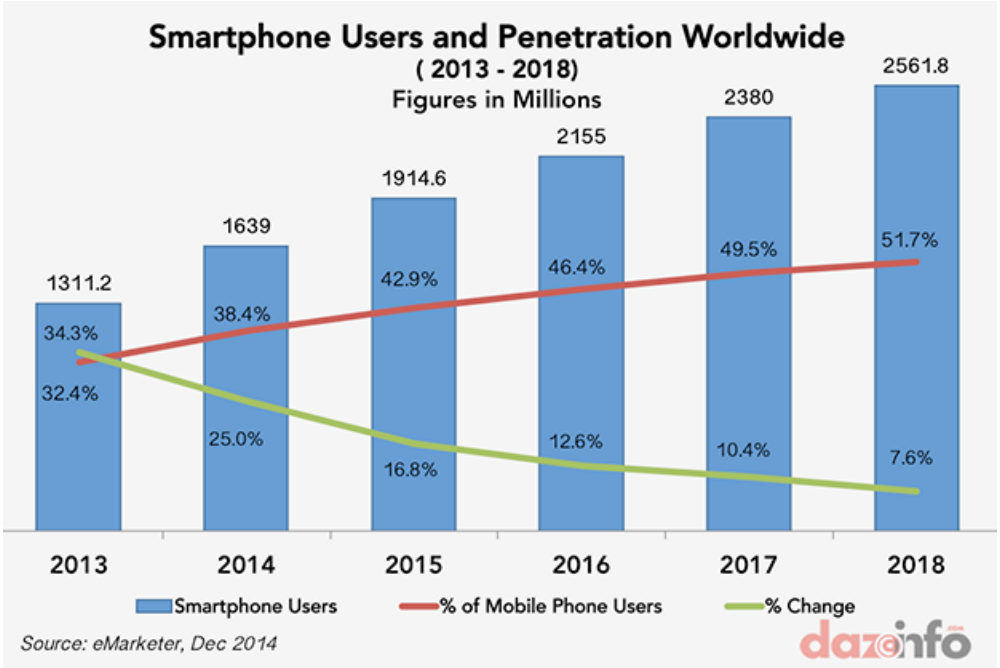

Fig. 1. The number of mobile phone subscribers worldwide.

It is a fact that mobile communications already has saved the life of many. Whereas, as far as the author knows, there is not a single case where it has been proven that the decease of a person was caused by telecom related electromagnetic radiation, medical and police help and rescue services rely heavily on wireless technology. It would be a real societal mistake to impede these services with too strong exposure limits.

It is a fact that exposure limits are actually mainly there for people living and/or working in the immediate neighborhood of base stations. Radiation exposure levels drop rapidly with distance from the radiating source. Disruption of services is mostly felt by people at the outskirts of the cell, or indoors, where the phones in the worst case have to work at levels down to around 1 mV/m. This level is many orders of magnitude lower than typical radiation exposure limits.

Finally, it is a fact that all of the above is valid for all forms of mobile communications, thus also 5G. Concerning the exposure aspect, intrinsically 5G is not different from 4G, 3G, etc. The physical form of radiation is exactly the same: electromagnetic waves propagating in space and carrying the information that has to be brought to the user. The only difference is the exact frequency at which this is done (for 5G in the range 2.4 – 4.2 GHz or at millimeter wave frequencies), and the way the information is "embedded" in the radiation.

3. The ALATA principle

The classical way of dealing with the problem of setting a radiation exposure limit is to ask: which levels of radiation are still hazardous for people and which are not? It is clear that this question is extremely difficult (read: impossible at this point in time) to answer. The worldwide scientific community involved in the issue, after decades of research, is still not able to provide a clear answer. Also, although no acute effects have been observed in the short term, the effect of EM radiation exposure in the long term is completely unknown. As said, nobody knows what the effect is of 50 – 60 years of exposure to levels for example of mobile phones. So the so-called "Precautionary Principle", a well-known principle in the EU, can be applied: "Union policy on the environment shall aim at a high level of protection taking into account the diversity of situations in the various regions of the Union. It shall be based on the precautionary principle and on the principles that preventive action should be taken, that environmental damage should as a priority be rectified at source and that the polluter should pay." The problem with the precautionary principle is that it is not very concrete, which leads to numerous interpretations.

We propose to tackle the problem in a different way. Given all positive societal effects of wireless communications, and since a democratic majority of the population does accept and even "needs" wireless technology, it is not feasible to set an upper radiation exposure limit in such a way that major problems would occur in the communication networks. Whereas it is almost impossible to define a limit based on health issues, it is very well possible, even easy, to define a maximum limit based on technical considerations. This just requires a technical study of the communication technology used in society nowadays. The question what this limit would be nowadays is thus relatively easily answered.

Consider for example the situation in Belgium. In 2005, the upper legal limit for radiation exposure between 10 MHz and 10 GHz in Belgium was set to 13.7 V/m under 400 MHz, $0.686\sqrt{freq}$ V/m in between 400 MHz and 2000 MHz, and 30.7 V/m above 2000 MHz. At the GSM frequency 900 MHz this yields about 20.58 V/m. This was a cumulative norm, taking into account all radiation sources. No fundamental network coverage problems occurred as a result of this limit. As a result of the federal structure of Belgium, in 2011, this Belgian limit was "completed" by regional Flemish legislation. Per radiating source, i.e. per antenna. the norm was lowered to 2.0 V/m under 400 MHz, $0.1\sqrt{freq}$ V/m in between 400 MHz and 2000 MHz, and 4.48 V/m above 2000 MHz. At 900 MHz this yields 3 V/m. Close to a GSM base station with a single operator, the allowed level was thus reduced almost by a

factor of 7. The remarkable thing is that still no real huge problems occurred within the network. The operators were perfectly able to adapt the network in the short term and at a feasible cost. However, in the Brussels region, the Belgian norm was replaced by a new, even stricter one, resulting in an allowed level at 900 MHz per operator of 1.5 V/m. This was a result of spreading the "exposure budget" of 3 V/m over the operators. It was found that this limit does create problems. From around 2012 – 2013, the operators were claiming that it was impossible to implement the 4G network under these conditions. This situation was resolved in 2014 by increasing the allowed exposure budget to 6 V/m. Now, in 2019, similar claims are stated by the operators about the deployment of 5G.

In the opinion of the author, this actually points out that the norms in Belgium are around the ALATA limit. It seems that the ALATA limit with the technology as it is deployed today, is between 1 and 2 V/m at 900 MHz. It is evident that similar limits could be used in other European countries, and even globally, since the situation in other cities and countries is not fundamentally different. Note that these levels are considerably lower the levels advised by the WHO and ICNIRP. This leads to the first main idea behind the ALATA principle:

Set the radiation exposure limits as low as technically achievable with present-day telecommunication technology.

Note that using this principle has several clear advantages.

1) For the ALATA principle, the fact whether adverse (small) effects have been proven or not is irrelevant. The huge societal controversy whether something can be considered as real proof or merely as an indication in a certain direction is totally overcome. Given the fact that electromagnetic radiation exposure cannot be considered as "toxic", since no drastic adverse effects have been found over the many years of research, the advantages of the technology clearly outweigh the health risks.
2) The principle also clearly gives a value for the norm: as low as technically achievable. Going even lower means that severe communication problems would occur, which is intolerable.

However, the ALATA principle also incorporates another idea, typical for the EM radiation exposure debate. Wireless technology is developing at a very rapid rate. An increased number of users, each requiring an increased amount of data to be transmitted, requires a constant upgrading of the existing networks, but also of the way how these networks are conceived. This means that the upper limits of today are not necessarily the upper limits of tomorrow. Indeed, even with the technology of today, rolled out in society, there is no fundamental problem in setting the allowed maximum levels down to 0.6 V/m. It just takes a gigantic reorganization of the whole network, which of course cannot be done overnight at a reasonable economic cost. This brings us to the second main idea behind the ALATA principle: "dynamic regulation", i.e. limits that become lower as the technology and its deployment become better.

The necessary measures have to be taken, to allow exposure levels to go down in the future.

However, implementing this requires actions of several stakeholders. The role of politicians is 1. to take care that independent research is sufficiently organized and funded, and 2. to establish up-to-date and feasible legislation and norms conformal to the situation at hand, i.e. for example following the ALATA principle. The role of the major economic stakeholders (manufacturers, operators, …) is to design, fabricate, and deploy equipment, not only taking into account the issue of the increasing demand for capacity, but also incorporating the foundations of the precautionary principle. This may require a shift in paradigm in some of the minds in these communities.

4. 5G systems

5G systems as they are being conceived and investigated today promise to implement several new technologies **that offer the possibility to reduce electromagnetic exposure**. Three prominent ways of doing this will be discussed here.

A. Increased number of smaller cells

The first and most obvious way to reduce radiation levels in a cellular communication network is to introduce more cells, each with a base station in the center. 5G promises to do this at an extreme level. At first sight, this sounds contradictory. However, the quality of the communication is depending on the received signal level. This signal level decreases with increasing distance. The speed of decrease is depending on the environment in which the network is deployed (shopping mall, city, countryside, …). Since the levels at the edges of a cell have to stay more or less the same in order to ensure communication there, if the size of a cell is reduced, the radiation levels in the center of the cell, where they are obviously the largest and where the exposure limits really matter, can be reduced. The compromise is thus more cells, each with a base station in the center, but functioning at a lower power, and thus at a lower radiation exposure level. It is easily calculated that, to the average, quadrupling the number of cells can be used to reduce maximum exposure levels with a factor 4 (expressed in V/m).
Increasing the number of cells is an issue that has been in the picture already since the introduction of the concept of cellular wireless mobile communications. However, this has always been from a coverage and network capacity point of view. As said, future 5G systems promise to deploy a huge number of small cells. Within the ALATA context the role of the operators is to proactively incorporate also the exposure issue while doing this. Just following the norms and regulations as they are imposed today is not sufficient. This requires a shift in mentality on their part.

B. Separate inside and outside communication

However, the paradigm of smaller cells can be brought to a next level. The fact that the ALATA principle hits a firm limit at this moment around 1 – 2 V/m (at 900 MHz) for the networks of today is entirely due to the fact that the networks have to cover both outdoors and indoors. Indoor coverage by a base station installed outdoors means that the signal has to travel through windows and walls, reinforced concrete, roofs, etc., while inside it still has to keep a sufficiently high level. It the system has to cover only outdoors, it would be easy to bring maximum exposure levels down to 0.6 V/m, a value promoted by the bio-Initiative [8]. There is thus an enormous "waste" of radiation, generating an enormous amount of electrosmog because the network was deployed as an "all-covering network".
One could imagine a situation where outdoor and indoor coverage is separated, see Fig. 3. The mobile networks, as we know them today, have to cover only the outside, while the inside is covered by other wireless systems. There are already a few good candidates in the picture. The first way is to use the numerous indoor functioning Wi-Fi systems, functioning in the 2.4 or 5 GHz bands. Such a system would require a mobile phone compatible with the two, which, from a technical point of view, is perfectly feasible, with technology that is essentially already on the market [10]. A second way is using the emerging wireless systems in the 5G millimeter wave bands. Since a few years, these millimeter wave systems are currently in full development at research institutes and in industry all over the world [9]. A mobile phone would have to switch seamlessly from the inside Wi-Fi or millimeter wave system to the outside network [11], [12]. As said, such a scenario would allow the reduction of maximum exposure levels drastically.

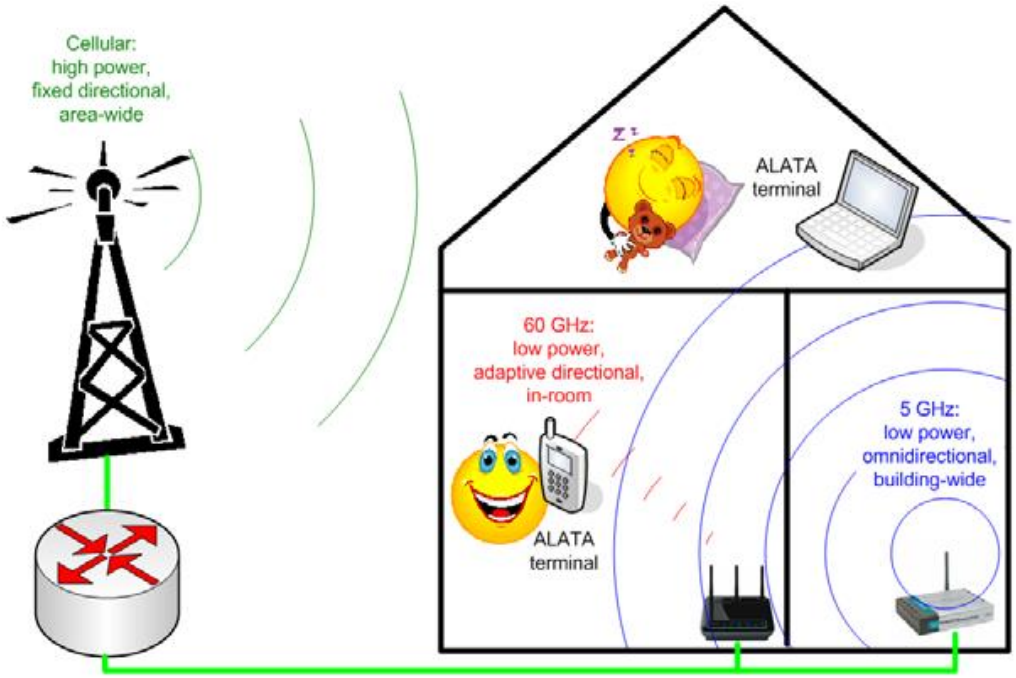

Fig. 3. Separation of indoor and outdoor communication.

In the perfect scenario, buildings are electromagnetically shielded, so that the signals outside and inside are to a large extent isolated from each other. This would have many advantages:

1. Interference issues outside – inside are drastically reduced, boosting the performance of the networks involved, both outside and inside.
2. The well-known "waveguiding effect", i.e. the fact that streets tend to guide the radiation waves over long distances, would be reinforced, again boosting the performance of the outside networks.
3. It would be much easier to control the levels of electrosmog generation.
4. It would be much easier to keep private indoor networks really private.
5. People inside would not be exposed any more to the mobile networks deployed outside.
6. Moreover, cautious or hypersensitive people would be able to avoid radiation all together if they really want.

The problem is that electromagnetic shielding up to now never has been an issue, not at a societal level, nor at a political level, and by consequence not in the construction industry. However, the same could be said about thermal insulation a mere 50 years ago. In many countries, especially in the Western world, thermal insulation is now obliged by law for new buildings.

C. Beam Steered Antennas

In the wireless systems of today, omnidirectional, hemispherical, or sectoral antenna systems are used. This means that they can practically be considered as spreading out the radiated power over a complete sphere, a half sphere, or a sector in space. This also means that by far most of the radiated energy is just wasted, since a specific user of course is located at one point in space. This way of working contributes enormously to the radiation exposure in society. It is very natural to think of systems that send radiation only in those directions in which it is actually received by the user targeted. The possible exposure reduction is considerable. In a so-called line-of-sight situation, i.e. where a straight line can be drawn between transmitting antenna and user, without any reflections on buildings (outside scenario) or walls (inside scenario), reductions by a factor 10 – 20 are easily reachable. This means that a norm can be reduced by a factor 3.2 – 4.5. The latter is more or less what is needed to go from the Flemish 3 V/m norm to the level of 0.6 V/m at 900 MHz, a level promoted by many stakeholders in this debate. The problem is that line-of-sight occurs only in rare circumstances in these systems. In most cases,

reflections occur and actually contribute to the communication. However, the feasibility of using beam steered systems in scattering environments has barely been investigated. It is the opinion of the author that even in the case of very scattering environments, they can be used as an efficient means to reduce the EM exposure.
The main problem with these antenna systems is that they are more complex and more expensive than the systems used today. No operator will consider a widespread deployment of these systems without societal or even legal pressure, since the main driving force for the operators is the system capacity needed, not the exposure issue, and there are simpler and cheaper techniques to increase capacity.

Conclusions

In this paper, the ALATA concept, meaning As Low As Technically Achievable, is explained and applied to the issue of electromagnetic radiation exposure. According to the opinion of the author, the allowed exposure levels in Belgium currently are more or less at the ALATA limit, which sets this country apart from many other countries. 5G incorporates many innovating technologies that cannot only be applied to increase capacity and performance of a system, but also to reduce exposure levels. In order to do that, it is advisable to align legislation to the ALATA principle so that there is a societal pressure for the manufacturers and operators to go in this direction. This means that, according to the author, increasing the allowed exposure levels, is not the way to go. Most applications envisaged within the context of 5G can operate very well within the current legislation. For extremely demanding applications (for example a wireless network monitoring and controlling self-driving cars), where increased radiation levels would be necessary at this point in time to ensure reliability of the network, further technological research is necessary to see how these can be implemented without having to increase the ALATA limits.

References

[1] http://www.who.int/peh-emf/project/en/

[2] C. Bianchi and A. Meloni, “Natural and man-made terrestrial electromagnetic noise: an outlook”, Annals of Geophysics, vol. 50, no. 3, June 2007, pp. 435-445.

[3] R. Iyare, V. Volski, and G. A. E. Vandenbosch, “Study of the Correlation between Outdoor and Indoor Electromagnetic Exposure near Cellular Base Stations in Leuven, Belgium”, Environmental Research, Vol. 168, pp. 428-438, 2018

[4] R. Iyare, V. Volski, and G. A. E. Vandenbosch, “Study of the Electromagnetic Exposure from Mobile Phones in a City Like Environment: the Case Study of Leuven, Belgium“, Environmental Research, Vol. 175, pp. 402-413, 2019

[5] G. W. Arendash, J. Sanchez-Ramos, T. Mori, M. Mamcarz, X. Lin, M. Runfeldt, L. Want, G. Zhang, V. Sava, J. Tan and C. Cao, “Electromagnetic Field Treatment Protects Against and Reverses Cognitive Impairment in Alzheimer's Disease Mice”, Journal of Alzheimer's Disease, vol. 19, no. 1, Jan. 2010.

[6] G. Draper, T. Vincent, E. Kroll, and J. Swanson, “Childhood cancer in relation to distance from high voltage power lines in England and Wales: a case-control study”, BMJ, vol. 330, 4 June 2005.

[7] http://www.zdnet.com/brussels-finally-gets-4g-after-politicians-relent-on-tough-mobile-radiation-cap-7000024218/

[8] www.bioinitiative.org

[9] http://www.digikey.com/en/articles/techzone/2013/jul/high-speed-60-ghz-wireless-connectivity-finally-takes-off

[10] http://www.taipeitimes.com/News/biz/archives/2006/12/14/2003340435

[11] http://en.wikipedia.org/wiki/Media-independent_handover

[12] http://en.wikipedia.org/wiki/802.21