On the use of Cognitive Radio for Decreasing Electromagnetic Radiation

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ABSTRACT
In this paper we identify how the new concept of Cognitive Radio could be used to decrease electromagnetic radiation in a general sense. In this paper, the consequences of this radiation should be understood in a wider sense. Here we consider the increase in noise level caused by electromagnetic waves as well as the possible health problems created by these waves. Classically, all progress made in the field of telecommunications is used to increase the spectrum efficiency. In this paper, we adopt another strategy, which is to use this progress to decrease the radiation level, whilst keeping the spectrum efficiency constant. We describe several methods, based on the new concept of Cognitive Radio, in order to achieve this.

1. INTRODUCTION

In this paper we study the effect of Software Radio [1] techniques and, more specifically, the effect of "Cognitive Radio"[2] on electromagnetic radiation. From our point of view, the main consequences of the increase in this radiation are considered to be possible health problems and an increase in the absolute level of electromagnetic noise.
For many different reasons, a public debate is currently underway on the possible effects of electromagnetic radiation on health. One of the main reasons for this is the exponential development of Base Stations. This debate is very complicated because, as usual, there are two opposing positions. The first one, mainly defended by operators and manufacturers, claims that "there is no risk", and the second position, defended by some groups (users associations, ecological associations, etc.) states precisely the opposite.
In this paper our aim, is not to take a position in one sense, but to identify and propose some original technical solutions for decreasing the potential risks. Today, when there is potential risk (for public health), whatever the domain concerned is, it is generally accepted than the "precaution principle" should be apply. The ethical thoughts tend to lead to a sudden awareness of all phenomenon, which endanger potentially the environmental balance. Therefore we can assess that we are answering to the public and medical requirements which propose to apply "Precaution principle" in this domain, like proposed by Prof. Zmirou in France in 2001 [3].
The general objective of our proposal is to reduce the public's exposure to radiation to a minimum that is compatible with a good quality of service. We can summarize our approach by saying "We would like to decrease the electromagnetic level by sending the right signal in the right direction when necessary."
In this context, using all the information on the user's environment provided by sensors, Cognitive Radio could obtain efficient and quick solutions. These solutions are based on Signal Processing techniques (equalization, channel estimation, "beamforming", smart antennae, etc.).
From a theoretical point of view, the gain in spectrum efficiency could be used to decrease the radiation level. However, from a practical point of view, all the actors in the telecommunications domain prefer to use this gain to increase the bit rate with a constant power level than to maintain a constant bit rate with a lower power level. Therefore, our approach seems to oppose these financial considerations. In fact, our technical solutions are accompanied by "political", "economical" and "sociological" questions, which will be presented in this paper.
The paper is organized as follows. The first section presents the problem by describing the electromagnetic propagation basis (subsection 2.1), in addition to the potential health risks (subsection 2.2). The second section briefly describes the concept of Cognitive Radio. The following section deals with our proposal for decreasing radiation. Taking into account the limited amount of space available in this paper, we only describe 4 examples of our proposal.

2. THE PROBLEM

Over the last few years, there has been a considerable resurgence in interest in wireless communication, and today it is one of the fastest growing sectors in the telecommunications industry. This step forward has not only expanded the wireless communications market, but has also created opportunities for newer products.
The number of heterogeneous wireless network services is increasing dramatically. In European countries there has been an explosion in the number of mobile communications consumers. Moreover, RLAN and HiperLAN also contribute to a growth in the number of wireless services. DAB and DVB-T are additional services in the broadcasting area. "Mobility" is one of the most important keywords behind these services. The main drawback of this explosion in services is that there is an increase in electromagnetic waves. For example, Figure 1 presents a partial vision of the spectrum efficiency for civil communications in France. We can conclude that there are no available bandwidths below 2GHz. This may explain the numerous projects offering digital communications in the 20, 40 and 60 GHz bands. If we consider the future Ultra Wide Band systems, ad-hoc networks and PAN etc., the level of radiation will increase on a local level, even if these systems are short-range and low power.

2.1 Electromagnetism propagation basis

The transmitted power of an emission signal is given by the following well-known equation: $<P>=\frac{P_e G_e}{4\pi d^2}\ W/_{m^2}$ where <P> is the Pointing vector or power density, P_e the emitted power, G_e the emission antenna gain and d the distance between the antenna and the measurement point.

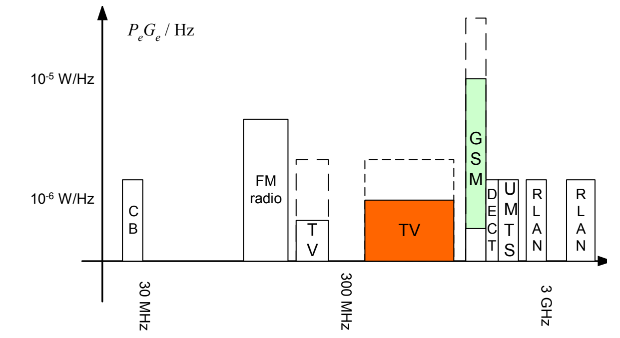

Fig. 1 : Standards spectrum in the 30 MHz-3 GHz band

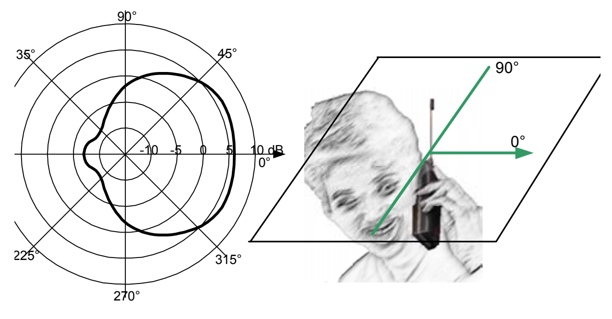

Fig.2: Electromagnetic Radiation near a Human Head

If the emission power is 1 Watt (GSM mobile Pmax = 2 W), the 41 V/m or 4,5 W/m^2 max. threshold is reached at a 0.13 meter distance from the emitter. This threshold corresponds to the acceptable level fixed by some eminent international organizations (IEEE, ICNIRP, CENELEC…). The more difficult the channel, the greater the power required. For example, if the signal needs to penetrate a building, a power ranging multiplied by 3 to 5 will be needed.
If we look at the radiation produced by an omnidirectional antenna close to a human body [4], this radiation divides into sectors in accordance with the distance from the obstacle (for example the human head in Figure 2). There is a great reduction (> 30 dB) in the direction opposite the main lobe. Therefore, a great part of the radiation (max. 50%) is absorbed by the human body.

2.2 Potential biological effects

Without being aware of the fact, we are all exposed to a great deal of electromagnetic radiation (both natural and artificial). The artificial radiation is generated not only by cellular phone services but also by more generally accepted services such as audio or TV broadcasting, computers, power lines, civil and military radars, etc.
According to the WHO, the radiation level close to a TV emetter are around 100 times higher than those found in nature, and the mean level has increased threefold in 30 years[7].

The sociological situation: The debate is not simple because what is at stake in terms of the economy, industry and public health is extremely important. This is a very controversial issue, and the answers are dualistic. In Europe, experts' reports have been published at a state level (Stewart in England, Zmirou [3] in France).
These reports with their somewhat ambiguous conclusions reveal that there is no proven risk to health. However, given the lack of certainty over this issue, the precaution principle should be applied. (for example: no base station antenna main lobes located within a 200 m radius of a school).

Precaution principle: (as defined in the Zmirou report): "the precaution principle is a political principle regarding the careful management of uncertain risks, which can apply as soon as there are plausible mechanisms or experimental or epidemiological observations that provide this principle with a minimum scientific basis.
The general objective should be a reduction in the average public exposure to the lowest possible level, which is compatible with service standards.

The health risks: they depend on the frequency band. According to WHO statement, there is no proven risk. Some works claim that, at low levels, EEG and blood pressure changes. Thermal bio-effects are quite well-known. The existence of non-thermal effects such as pressure changes, effects on biological cells are mentioned in [5] and [6].

Some questions remain unanswered:

- Is it better to have lower intensity emissions but for a longer period of time?
- What are the possible health effects of exposure to the upper bandwidths (20, 40 and 60 GHz)?

A great deal of work out on these effects has been carried within European Commission programs: COST 281 Project, REFLEX, PERFORM A, CEPHOS, Eureka Project SARSYS.
However, as far as we know, no-one is studying possible solutions to avoid these effects, such as those we present in this paper.

3. THE COGNITIVE RADIO

The Cognitive Radio concept, here tackled in its widest and most unrestricted sense, refers to a communication system that is able to observe its environment, analyze it, and react to it in some way. This kind of control loop is illustrated in Fig. 3.

In addition to its multiple communication parts, the CR system features *sensing* means, *adapting* means and a *smart* sub-system dedicated to analyzing *stimuli* and making *decisions*.

Sensing means refer to all the possible methods the CR system has at its disposal for observing its environment, which can be categorized in four main families described below:

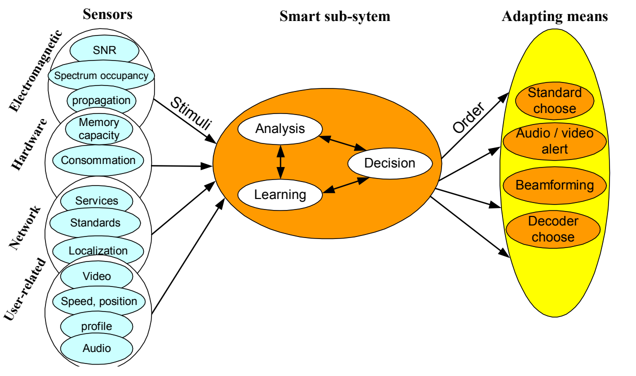

Fig.3 schematic view of a Cognitive Radio system

- *electromagnetic environment*: spectrum occupancy, Signal to Noise Ratio (SNR), multi-path propagation…
- *hardware environment*: battery level, power consumption, computational resources load,…
- *network environment*: telecommunication standards (GSM, UMTS, WiFi, etc.), operators and services available in the vicinity, traffic load on a link…
- *user-related environment*: position, speed, time of day, user preferences, user profile (access rights, contract…), video and audio sensor (presence detection, voice recognition)…

As shown in Fig.3, all the stimuli received by the sensors from the different layers (from physical to application) must be merged and analyzed jointly in order to reach the best possible decision.

4. OUR PROPOSAL

In this section, we will describe 4 examples of how using the Cognitive Radio to decrease electromagnetic radiation.

Remark **:** Among all the sensors described in the previous section, only some of them will be used in the framework of this paper.

4.1 First example: Network Management

a. presence signal

It may simply be a matter of only emitting the presence signal (GSM) when the mobile position changes at a given speed. The sensors (localization, speed,…) provide information on the possible cell change. This is a complete reappraisal of the current protocols, which work with a permanent presence signal. This proposal deals with the emission of a movement signal or even a "handover" anticipation or network exit signal.

This strategy has a considerable impact on the whole network and also on electromagnetic radiation and power consumption.

b. choice of the standard and/or the operator

The terminal or the Base Station could recognize the spectrum occupancy and therefore decide which band (with the associated power) is the best from the point of view of electromagnetic radiation. This could be performed thanks to the standard recognition sensor.

4.2 Second example : Beam forming with smart antennas

The smart antenna sensor could be used in many situations, locally as described in *a*) or from a network management point of view as in *b*).

a. Smart antenna to avoid the head ,

This example consists of forming the antenna emission diagram in such a way that it sends the lowest amount of radiation towards the user.

Thanks to the appropriate sensors, the terminal will be informed of its exact position with regards the user's head. With the help of smart antenna techniques or sectoral antenna technology, it will then be able to form the radiation diagram in order to reduce (and even cancel) the radiation emitted towards the user. This involves mobile positioning and real-time antenna diagram calculations. One effect of antenna sectorization, which concerns us directly, is a great reduction (>30 dB) in the direction opposite the main lobe, this is good for mobile phones, since it makes it possible to reduce the waves in a person's head and body .Compare Figures 4 and 2.

It is therefore a good idea to use treatment antennae for mobile phones. From this perspective, Base Station localization research done by the mobile, and mobile incoming power direction research are necessary.

b. Network management

It is possible to perform exactly the same processing in the base station. This imply to precisely localize the mobile.

Figure 4 shows the power distribution generated by the base station antenna towards one mobile phone. This simple example is not new. In fact, this type of processing is already use in order to increase the number of user in a cell.
The question here is: can an operator accept to use this gain for the same user number instead of increasing the user number?

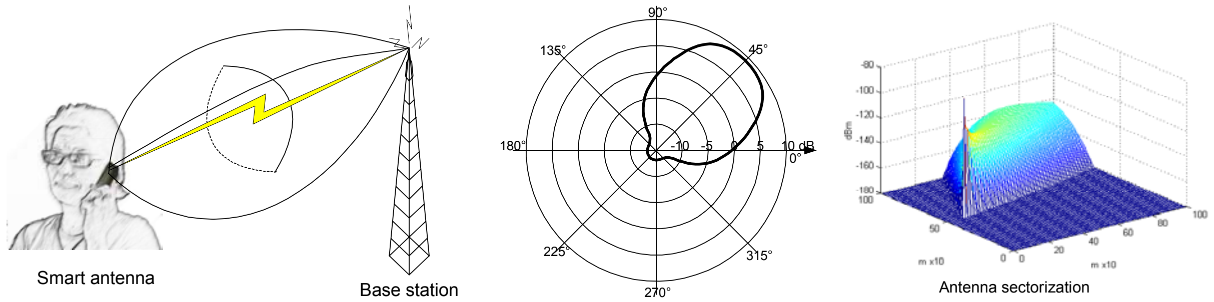

Fig.4 : Antenna beamforming

4.3 Third example : Spectrum efficiency optimization versus power transmission.

The terminal (or base station) will be able to determine the transmission channel quality in real time and, in accordance with this quality, the emitted power will be adapted in real time in a manner more effective than the one that is currently used. This simple example is not new. In fact, several norms today in standardization process, already include this type of processing. That means that Cognitive Radio is taken into account even it is not so clearly stated.
After the receiver has checked the quality of the transmission – i.e. to see if there is good SNR, good channel estimation and sufficient BER for the desired QoS – it can then decide to use a channel code in order to decrease the SNR whilst keeping the BER sufficient for the QoS. Similarly, it could also decide to change other parameters of the physical layer with this objective in mind. For example, it could decrease the symbol frequency if the reception duration is compatible with the QoS.
Question: Can an operator accept to use these parameters to decrease the SNR for the same bit rate instead of increasing the bit rate for the same SNR?

4.4 Fourth example: CR/Users interaction

A signal is generated to alert the user that he/she is in a vehicle and that it is in his/her interest to put the mobile phone back in its holder or to turn it off (common sense actions). Likewise, the user can be warned that he/she is in a bad position with regards the closest base station (see here the interaction with example 2.a) and that he/she should thus reduce the emitted power or avoid cross body emission.
It is therefore possible to imagine numerous other configurations, which provide the user with information on his/her electromagnetic wave exposure rate.
Questions: Can an operator make a selling point out of the fact that its mobile phones emit less radiation than those of its competitors? Are users prepared to pay more for a less polluting mobile phone?

CONCLUSION

In this paper, we have shown that it is possible to use Cognitive Radio in order to decrease electromagnetic radiation. This technical possibility does not hide the political and economical aspects of this problem. In fact, we ask several questions such as: is there a market for cognitive radio terminals that take into account this “ecological” aspect of electromagnetic transmission? Is there a financial argument for operators wishing to find the best compromise between health, spectrum efficiency, power consumption and cost etc.?
The next step will be to describe more examples in a future paper.

REFERENCES:

[1] J. Mitola. The software Radio Architecture. IEEE Communications Magazine, May 95, pp. 26-38.
[2] J. Milota. Cognitive Radio. PhD Dissertation from the Royal Institute of Technology, May 2000, Sweden.
[3] Dr Zmirou. Rapport à la délégation Générale de la santé (in French). January 2001.
[4] S. Koulouridis, K. S. Nikita. Study of the Coupling Between Human Head and Cellular Phone Helical Antennas. IEEE Trans. On Electromagnetic Compatibility, Vol. 46, No. 1, Feb. 2004.
[5] D. Leszczynski and al. Non-thermal activation of the hsp27/p38MAPK stress pathway by mobile phone radiation in human endothelial cells: Molecular mechanism for cancer- and blood-brain barrier-related effects. Differentiation 2002 May, 70(2-3):120-9.
[6] D. Panagopoulos, A. Karabarbounis, L. Margaritis. Mechanism for action of electromagnetic fields on cells. Biochem Biophys Res Commun 2002 Oct 18; 298(1):95.
[7] Establishing a Dialog on Risk for Electromagnetic Field. http://www.who.int/emf.