

# Technological Lock-In Effects: A new Challenge for RF Health Risk Management?

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**Abstract**— This paper assesses the risk of lock-in effects in wireless communication technologies. Regulations and public opinion sometimes hinder the use of certain technologies without scientific evidence of risks. Public opinion and its influence on lock-in effects are investigated, using results of a survey among 12'000 people at ETH Zurich.

## I. INTRODUCTION

Wireless technologies have been used for many years in different areas of industry. Its importance for companies and society is ever growing, increasing dependency: the choice of a certain technology for use in a process or in a product leads towards path dependencies which are reinforced with every investments in a specific technology direction [1]. Applied technologies fulfill a necessary task within companies and it is getting more and more difficult to substitute them. Such a development may result in a technology lock-in [2].

The perceived usefulness of technologies is dwindling with an increased standard of living and with its ongoing use. This makes possible brisk refusals of technologies with perceived adverse effects, without antecedent analysis of utility and dependency [3],[4]. Health risks are often categorically refused and are therefore not negotiable. Regulatory actions assure that these risks are kept as low as possible. From a company perspective, these regulations pose sometimes unexpected economical and technological boundaries [5]. Combined with path dependencies, companies may end up in technology traps [6]. This paper assesses public perception of wireless technologies, leading to a better understanding of the risk of public refusal with a survey among some 12'000 students at ETH Zurich.

## II. METHODOLOGY

Many issues influence public perception of wireless technologies. To prepare the general overview, students were selected and in an interdisciplinary workshop at ETH Zurich 5 major areas of potential influence were defined:

- Security and privacy

As soon as security issues of wireless technologies arise, people closely observe infringement of their privacies. If security is not obvious, potential personal damage is weighted against personal utility.

- Any form of radiation

As radiation is perceived as potentially dangerous by many people, attitudes and personal behaviors towards this side-effect are analyzed.

- Activities in self-protection

An obvious way to ease exposure lies in means of self-protection. It is investigated, whether people understand wireless communication technologies and know how to protect themselves against radiation. Although radiation is seen as a negative externality, better understanding would relieve momentum in potential refusal, as besides banning or allowing a particular technology, individuals could have to a certain extent self-control over their personal exposure.

- Communication and media

Scientific knowledge about harm of radiation is weak; apart from direct thermal effects, there is a lack of evidence of any non-thermal effects [7]. As the general information situation is unclear, communication and media could take the role of opinion leaders and thereby substantially influence public opinion.

- Negative externalities and personal benefit

Acceptance of negative externalities is low, especially if no personal benefit can be extracted. Therefore refusal could be possible, especially in wireless technologies where negative externalities and benefits are not evenly distributed. Attitudes towards different sources of radiation are analyzed.

- Technology speed of wireless products

Is technology developing at a high speed? If so, it is to be expected that scientific knowledge of side effects and therefore regulation of latest technologies are lagging. This gap opens when technological development outpaces scientific knowledge of risks involved and the associated regulation (Fig. 1). Then side-effects might arise on a “case by case”-basis, awaiting scientific clarification. During this unregulated period acceptance of technology may dwindle leading to public refusal.

These five possible triggers were assessed in the survey using scenarios related to situations and opinions, in order to avoid asking obvious or leading questions.

Of 12'464 students addressed in the sample at ETH Zurich, 1'754 agreed to respond to the survey, of which a remarkable 1'321 completed it. This equates to a 10,6% return rate.

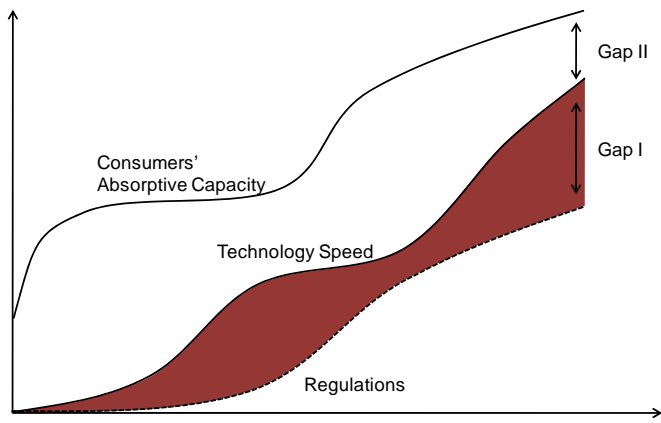


Fig. 1 Regulation gap induced by high technology speed

### III. RESULTS

#### • Security and privacy

The majority of respondents using wireless equipment tended to accept a certain level of risk in security and privacy, but less frequently high risks, whereas 15% of all respondents tend to avoid all kind of risks involved (Fig. 2).

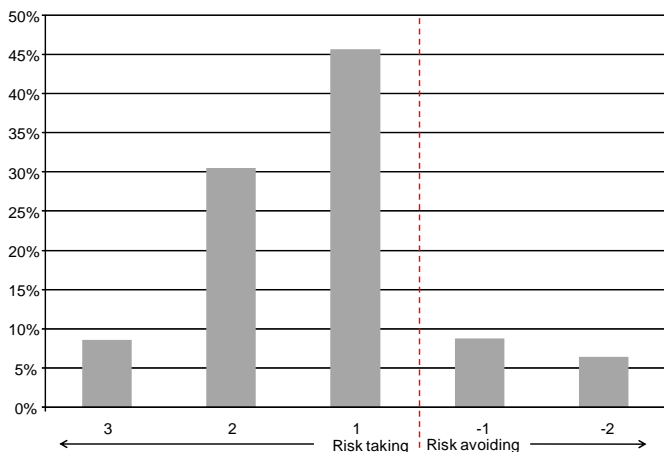


Fig. 2 Attitude towards security and privacy risk

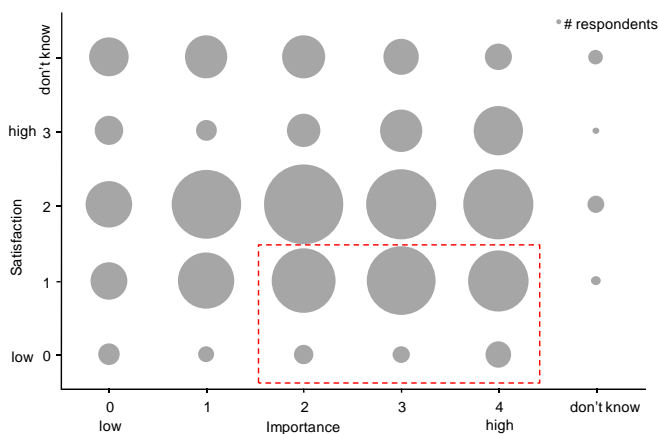


Fig. 3 Importance of security and privacy against overall satisfaction with security and privacy

A satisfactory level of security and privacy is seen by 54%, whereas 32% see the desired level not granted, but thereof 3% don't care (Fig. 3). The combination of a perceived unsatisfactory security and privacy level combined with high importance figures holds some negative potential towards refusal. Although 29% indicated their objections in this area, a distinct attitude towards risk taking eases this potential to only 5%, as 24% of all wireless communication equipment users therein are "risk takers" and are ready to accept an individually bearable level of risk.

Security and privacy seems to be an issue among a noticeable part of the respondents, though it is a clear minority. But it is not to be neglected, some negative potential is present, and activity against technologies with undesired side-effects is expected to be highest among unsatisfied people. Sometimes overall opinion is led by a minority of opinion leaders. As only skilled people are capable of identifying security and privacy flaws in wireless technologies in depth, it remains to be analyzed whether experts and opinions leaders happen to be part of those 29%.

#### • Any form of radiation

As knowledge about the existence of certain technologies is a prerequisite for refusal it has been investigated if common wireless technologies are known. Many wireless technologies such as RFID, DECT and ZigBee are not known yet by all respondents (Fig. 4). This is especially for RFID and DECT surprising, as those technologies are widely used in everyday life. RFID tags are used to tag retail goods. DECT is a wireless standard for wireless telecommunication in home areas. DECT is currently the only standard for wireless telephones, apart from the phase-out technology CT1+. DECT in particular has encountered a wave of public refusal as consumer protection organizations picked up this technology, reprehending that these products constantly emit radiation, also in idle mode.

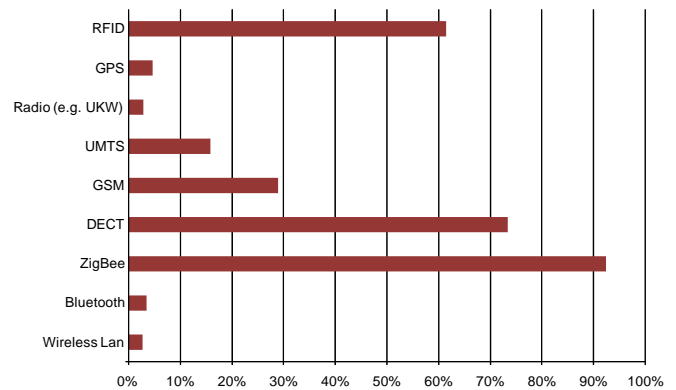


Fig. 4 Unknown wireless technologies (percentage of respondents who did not know about the existence of a certain technology)

Radiation might be more easily accepted, if the functional benefits of the products compensate for this side-effect. Therefore respondents were asked, whether they would be willing to accept additional radiation if they'd get better functionality than their current mobile. The opposite situation was looked at as well: If respondents would change their

current mobile into one with less radiation but also less functionality. The results show a tendency towards radiation avoidance (Fig. 5, Fig. 6). More functionality would not compensate for additional radiation for 61% and 48% would even accept less functionality for a reduction in radiation.

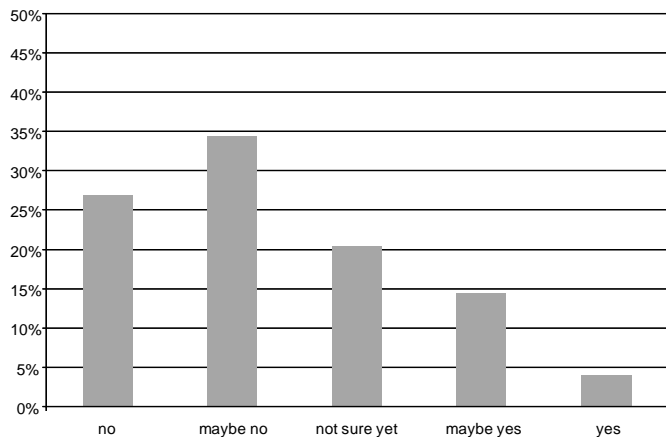


Fig. 5 Additional functionality cannot compensate for radiation refusal (percentage of respondents who seek for additional functionality accepting extra radiation)

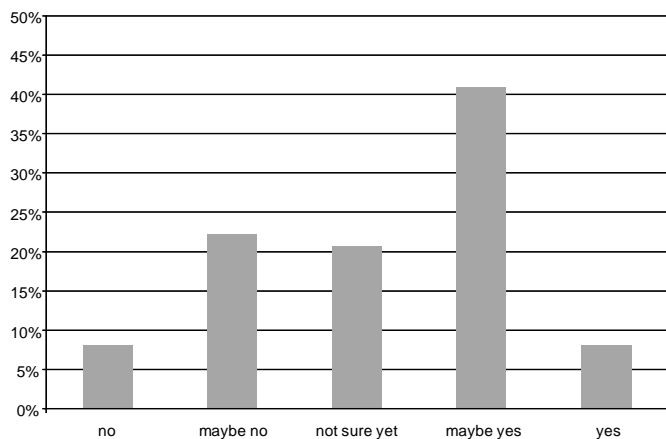


Fig. 6 Reduced functionality would be accepted for achieving less radiation (percentage of respondents willing to reduce functionality in order to get less radiation)

Although it has to be questioned whether responses were due to the topic of the survey being biased towards radiation avoidance, it remains a respectable result. More respondents are not willing to trade functionality against radiation if radiation is increased. But if radiation is lowered then there is readiness for compromises in functionality. Thus decisions are being made product functionality independent.

Radiation may be the tipping point for consumer decision. Customer desired product functionality has been achieved already for some time or products are even over engineered. Thus people begin to take notice of other product attributes. This normally happens when little innovation potential remains to be harvested. In this situation product design or reduction in negative externalities might start to play a more important role. In the survey 48% of respondents followed this pattern.

In addition, 82% of respondents didn't see themselves sensitive to radio radiation. Whereas 15% thought that they are modestly sensitive, 3% affirmed a certain influence by radio radiation.

• Activities in self-protection

If consumers know how to protect themselves, they may more easily accept certain negative externalities. For example, by knowing not to cover cellular antennas with their hand whilst talking, as this would allow to achieve the same signal quality with up to 2W less radio power. Or by understanding how to protect wireless networks, that security and privacy can be ensured. First of all, one has to believe that these actions are effective.

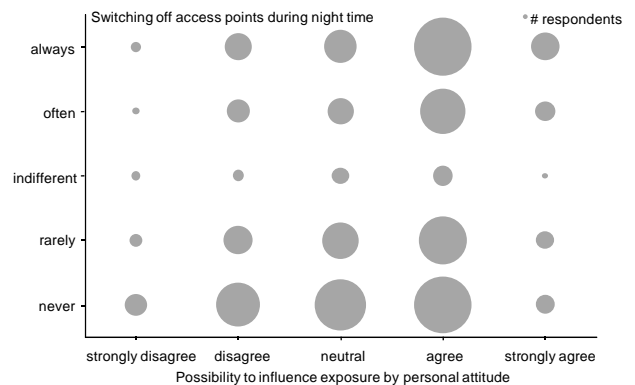


Fig. 7 Respondents who switch off wireless access points in order to avoid exposure, against their personal perception of effectiveness of self-protection

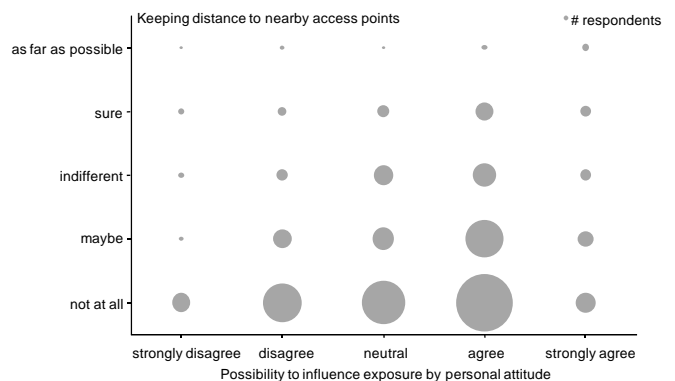


Fig. 8 Respondents who keep a certain distance to access points in order to avoid exposure, against their personal perception of effectiveness of self-protection

Wireless access points can be switched off, but avoiding proximity to access points in everyday life is more complex and does often not depend on individual will (Fig. 7, Fig. 8). As expected, respondents tend to master the simpler task more easily as less hassle is involved. Though switching off wireless access points seems to be a more polarizing question. Either you do it always or you never do it. This is the well known division of risk-behavior into "mushroomers" and "stuntmen": Followers of the precautionary principle and followers of "nature and technology are benign" respectively. The expected influence of belief in effectiveness of self-

protection and activity in self-protection can't be seen in the data.

Interesting is the big number of respondents who, although they see effectiveness in means of self-protection, don't attend to it. Either those respondents don't see negative effects associated with radiation or they simply don't care and value hassle free use of wireless communication devices over a reduction in exposure. In the first example 40% and in the second one 7% of the respondents are active in self-protection. Thus, it seems to depend heavily on the effort needed for people to actively manage their exposure. Furthermore, if knowledge of wireless equipment and radiation is absent, motivation and effectiveness of self-protection strategies would be lower. At least a good level of knowledge and understanding of wireless communication devices would be expected to ensure that people would be capable of effectively protecting themselves (Fig. 9). Of the respondents, 46% indicated that they had at least a good level of knowledge capable of implementing effective self-protection strategies.

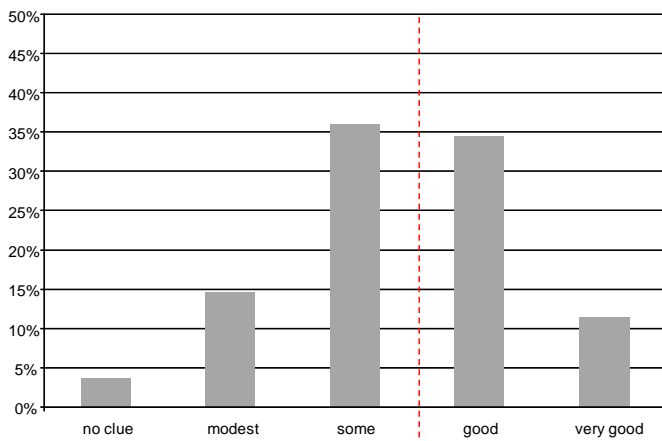


Fig. 9 Perception about personal knowledge in wireless communication technologies

Although there seems to be some potential in self-protection it is to be questioned if people do have the necessary knowledge, belief in the effectiveness and are willing to carry out the hassle of actively managing their own protection. Therefore it is to be questioned if self-protection really would ease a public refusal of wireless communication technologies.

• Communication and media

As information about wireless communication technologies and their possible side-effects is scarce, different information channels are used to seek for evidence about the overall situation. Public media seem to be for the majority of respondents the most important information channel (Fig. 10).

Confronted with news about negative side-effects, 60% of respondents who received the information described their reaction as surprised and worried, only a small minority was shocked (Fig. 11). Though when asked what and if they would undertake action, if scientific evidence would be found, only 31% would take action and only 3% thereof would immediately change their equipment (Fig. 12).

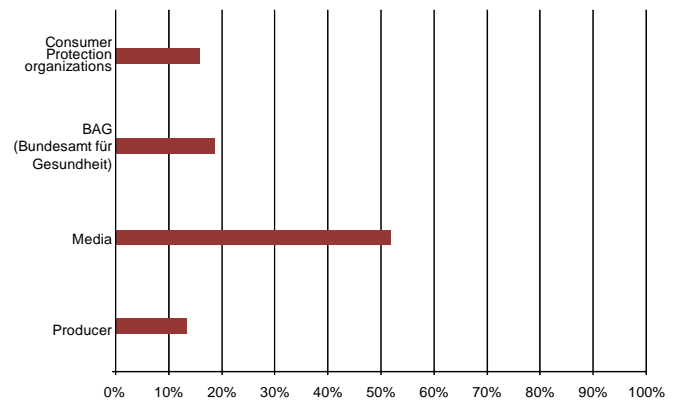


Fig. 10 Perception of most influencing information channel

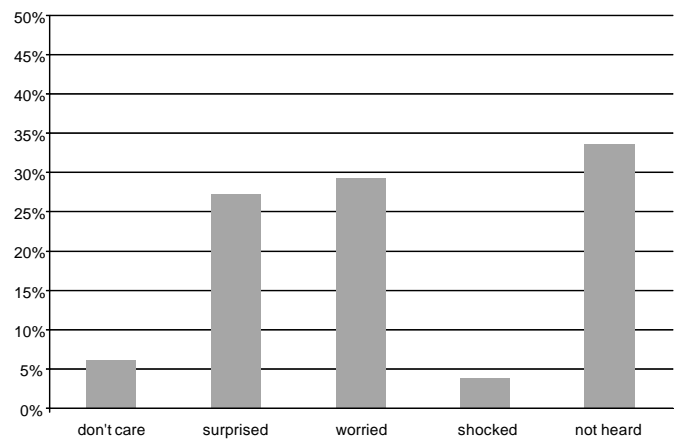


Fig. 11 Reaction on news about negative side-effects caused by radiation

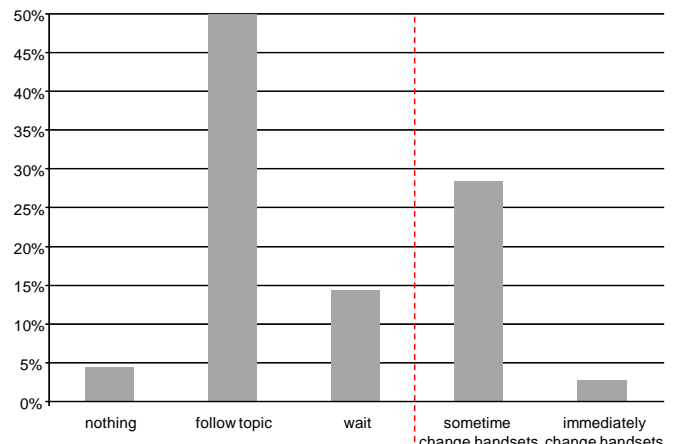


Fig. 12 Immediate action after scientifically assured side-effect

Hence ongoing use of existing equipment and technologies leads to confidence. Use of products over a certain period without any directly related negative side-effect, is perceived as absence of evidence of harm. This holds true also for perceived danger of use of television- and radio-antennas. 47% of respondents don't see any danger in the case of television emitter antennas, whereas 64% don't see any exposure by radio antennas (Fig. 13, Fig. 14).

As radio antennas are an older application of wireless technologies than television antennas they presumably get

accepted more easily. This reinforces the expectation, that older technologies or applications achieve a certain level of confidence with time of usage. As expected side-effects of radiation occur only with ongoing repeated exposure, immediate action might not be seen necessary; therefore no straight harm is to be expected by ongoing use. In contrast the change of handsets directly leads to additional costs. Respondents might have underestimated radiation in this case.

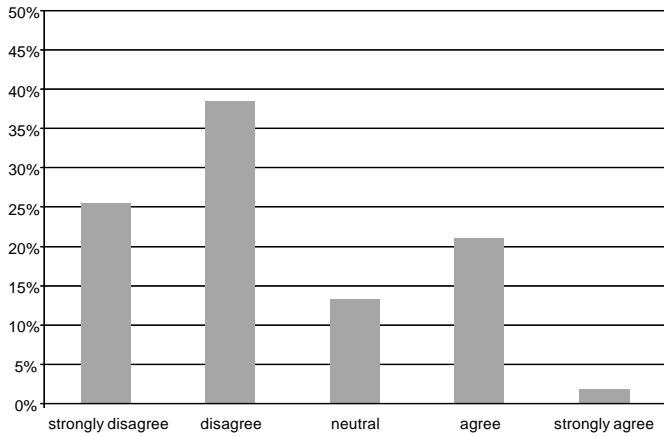


Fig. 13 Percentage of respondents who see health risks by emitting radio antennas

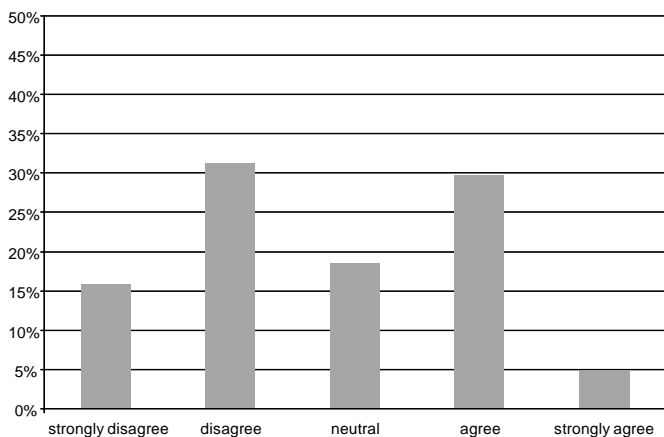


Fig. 14 Percentage of respondents who see health risks by television antennas

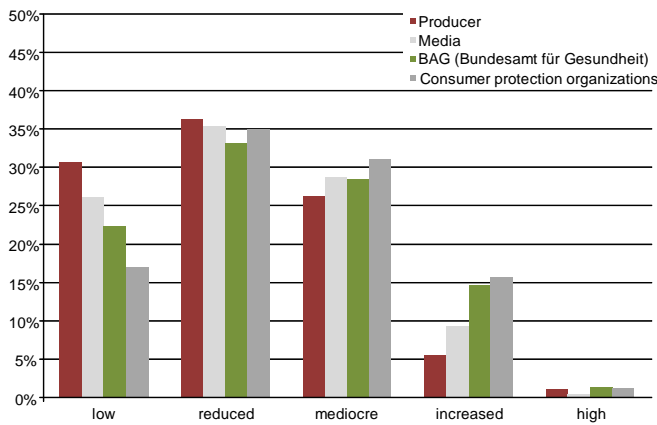


Fig. 15 Credibility differs among information channels

Another reason for no immediate or delayed action might be explained by the fact, that credibility of information channels is generally weak (Fig. 15). Among the different channels there seems to be a pattern in the categories of low, mediocre and increased credibility. Consumer protection organizations and BAG (Bundesamt für Gesundheit – federal bureau for health) achieve highest level of credibility, producers and media are the laggards. This result was expected, as consumer protection organization and BAG strive for protection of consumer needs.

This result might stem from the fact that the evidence base is known to be generally weak. Respondents don't expect any solid information yet, as scientific research is not sufficiently progressing. Therefore any information, origin independent, is considered weak. This information is supported by a wildcard field in the survey, as 5% of all respondents see "absence of scientific results" or equal formulations as the main reason for current absence of media interest.

• Negative externalities and personal benefit

Radiation is emitted to others not directly profiting from a specific base station, whereas personal handsets have personal value. Hence, negative externalities to a third party are only expected from base stations. Nevertheless there seems to be a recognizable correspondence between avoidance of base station radiation and handset radiation. There seems to be a tendency towards disinterest of radiation as such, as well as 42% consistently never try to avoid radiation. Only 10% show a consistent avoiding-attitude (Fig. 16). The rest shows semi-consistent attitudes as it differentiates between base stations and handsets whereas handset radiation is more often avoided than base station radiation.

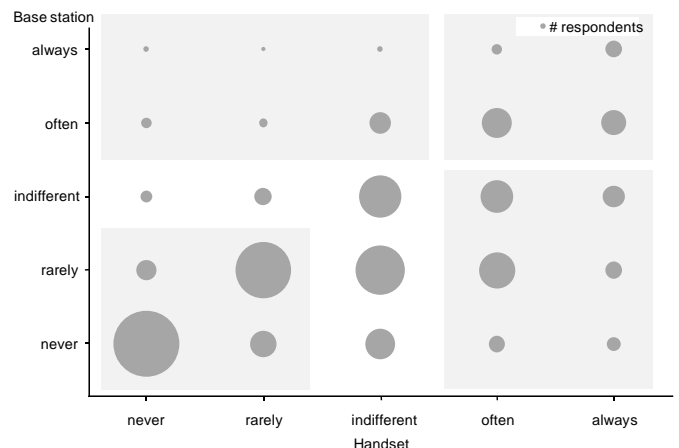


Fig. 16 Avoidance of radiation emitted by base stations and handsets

It seems that our respondents take action where it is feasible, thus avoid radiation of handsets more often than they try to reduce exposure to base stations. The reason might be twofold. Firstly, avoidance of proximity to base stations is a much more complex task, as it is not always noticeable where they are located and over what distance information is transmitted. Secondly, trying to change the set up of base station antennas is often a long and cumbersome process. Though it is not yet clear whether "acceptance" of radiation

emitted by base stations can be set equal to general acceptance of negative externalities. First of all it depends on the effect and amount of negative externalities and second the barrier to successful counteraction might be too high for many people. Thus tendency towards avoidance of handset radiation presumably lies in the favorable cost-benefit ratio. Hence negative externalities don't seem to play an important role for refusal of a technology in this setup. Radiation is considered source independently.

• Technology speed of wireless products

If technology is developing at high speed, it is to be expected, that scientific knowledge about side effects is lagging and therefore regulation is not adapted to actual products in the markets

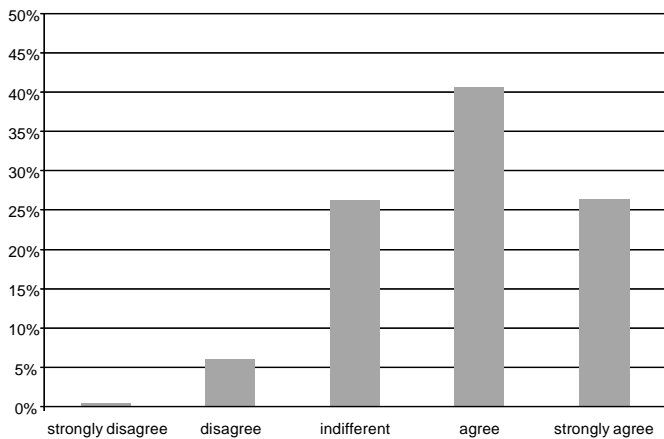


Fig. 17 Perception of technology speed in wireless communication technologies (percentage of respondents who see high technology speeds in wireless communication devices)

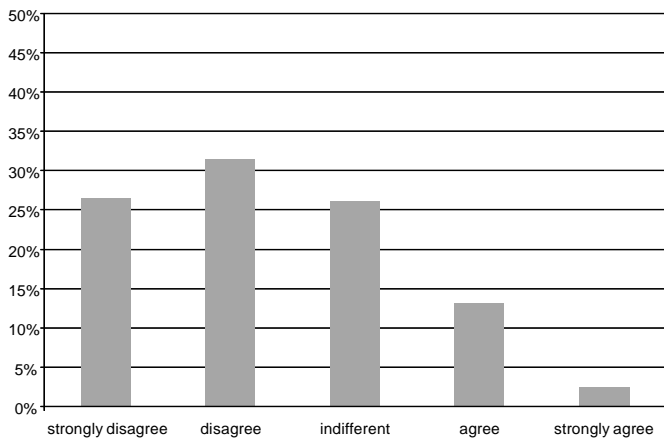


Fig. 18 Perception of technology speed of wireless communication technologies outpacing absorptive capacity (percentage of respondents who agree, that technology is outpacing regulation)

High technology speed might not only outpace regulation but also the absorptive capacity of customers. Although a dizzying 67% see technology developing at high speed, only 16% see this development outpacing their absorptive capacity (Fig. 17, Fig. 18). Regulation is still lagging due to absence of scientific evidence. This enforces the receptiveness for any information, as no assured facts are available. In this fluid

phase public opinion is difficult to foresee and easy to influence by opinion leaders or even by media.

IV. DISCUSSION

The 11% return rate shows a high sensitivity to this survey topic. Although not yet indicating any trend as such, awareness to these issues seems to be high.

Overall security and privacy situation seems to hold some refusal potential, as a noticeable minority of 29% of respondents are unhappy with security and privacy protection. However wireless communication technology users seem to be ready to accept a certain level of risk involved in order to get wireless freedom. It is not sure yet how this attitude is going to develop as opinion leaders might play a crucial role. Possibly they are also among this 29% of critical respondents.

Though in direct comparison to product functionality, there is a distinct tendency towards radiation avoidance, to the point of accepting lower functionality of mobile phones, in order to be able to further reduce radiation, although personal sensitivity towards radiation seems to be generally low. Attention towards currently publicly discussed topics, such as DECT phones, is sometimes absent, not all respondents even knew this technology.

Self-protection could to a limited extent give back control over radiation to individuals. But means have to be simple, as knowledge about wireless communication technologies is not always solid and motivation decreases with complexity of actions involved.

Scientific knowledge about radiation is generally weak; therefore information channels have low credibility, although consumer protection organizations and BAG edge a little higher. News about wireless technologies clearly influence respondent's perception. But direct actions are not to be expected, as changes in equipment always entail additional expenditures. It is not to be neglected that regulators usually decide over third party's equipment. Additional breakthrough-information may very well influence public opinion, whereas pieces of the information puzzle as such, are almost neglected.

Respondents take action where it is feasible and needs little effort, neglecting reflections about negative externalities. Respondents take action more towards avoidance of exposure to handsets, than to base stations. This can't be interpreted as an acceptance of infrastructure radiation as such. Looking at opinions in the immediate neighborhood of a base station might result in different results. Thus refusal against wireless networks might start in a small nucleus in the vicinity of base stations. All in all current attitude towards radiation of wireless networks does not reach high awareness in general.

Respondents believe that technology is developing at high speed, though in general consumers manage to keep pace with this evolution. But regulation is still lagging behind; this can be seen by the fact, that safety limits are multiples of the proposals of the scientific community. As knowledge is still weak in order to assure security, high security margins are added.

## V. CONCLUSION

At the advent of first indications of a trend towards acceptance or refusal, opinions will be made fast. Once opinion is toppling over, triggered by some opinion leaders, little time is expected to remain for adaptations. This will happen very quickly as sensitivity seems to be high and scientific evidence is not sufficient. Security and privacy are currently not strong drivers behind a potential refusal. Also radiation is not yet an issue as such, but weighting up radiation against product functionality there is a clear tendency towards radiation avoidance, though self-protection is attributed little success. Respondents tend to take action where it is feasible and needs little effort. Because technology seems to be developing at high speed, break-through scientific information or strong opinion leaders would be needed in order to substantially change public opinion.

In a situation where companies are tied up to certain technologies either by investments in facilities or in

knowledge and public opinion is fickle combined with high public visibility, cautious and long-sighted technology monitoring is needed. A systematic surveillance of weak signals is advised for companies involved in wireless technologies.

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