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

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***Abstract*— This paper assesses the danger of technological lock-in effects in wireless communication technologies. Regulations and public opinion sometimes hinder the use of certain technologies without scientific evidence of risk emanated by these technologies. Public opinion and its influence on lock-in effects are investigated, using results of a survey among 12'464 people at ETH Zurich.**

I. Introduction

Wireless Technologies have been used for many years in different areas of industry. Thereby its importance for companies and society is ever growing, simultaneously increasing dependency. The choice of a certain technology for use in a process or in an end-user product leads towards path dependencies which are reinforced with investments in a certain technological direction [1]. Applied technologies fulfill a necessary task within companies and it is getting more and more difficult to substitute them. Thus this development results in a technological lock-in [2].

The publicly perceived usefulness of technologies is dwindling with an increased standard of living and with its ongoing use. This has a tendency towards brisk refusal 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]. Concurrently due to technological path dependencies, companies are tied in technological traps [6]. This paper assesses sentiment in public about wireless technologies, leading to a better perception of the danger of public refusal. Investigating this issue in a survey among 12'464 students at ETH Zurich, results are presented in this paper.

II. Methodology

Different triggers influence public perception of wireless technologies. In an interdisciplinary workshop at ETH Zurich 5 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 completely granted, personal damage is weighted against personal utility.

- Radiation

As radiation might be perceived as potentially dangerous, attitudes and personal behaviors towards this side-effect are analyzed. Considerations regarding negative externalities are also considered below as another area of influence.

- Activities in self-protection

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

- Communication and media

Scientific knowledge about harm of radiation is still weak; apart from direct thermal effects on creatures, 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

As radiation is a negative side-effect, it is to be considered as a negative externality as the entire population gets exposed regardless of personal advantage or usage. Acceptance of negative externalities is expected to be low, especially if no personal benefit can be extracted. Therefore refusal could be possible, especially in technologies where negative externalities and benefits are not evenly distributed. Attitudes towards different sources of radiation are analyzed.

- Technology speed

Is technology developing at a high speed? If so, it is to be expected that scientific knowledge and therefore regulation of latest technologies are lagging. This gap opens when technological development outpaces scientific knowledge of risks involved and the associated regulation, as shown by gap I in 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.

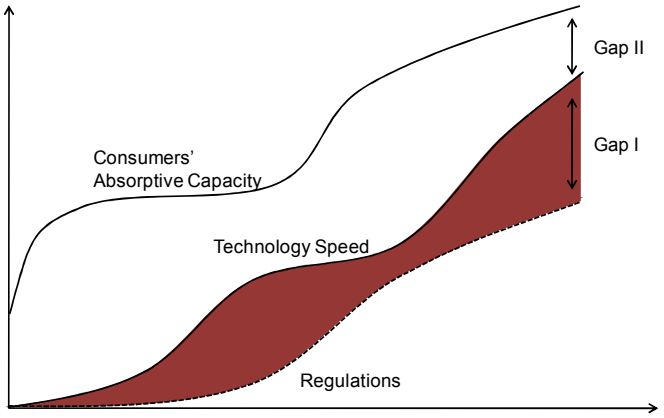

Fig. 1 Regulation gap induced by high technology speed

III. Results

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.

- Security and privacy

As depicted in Fig. 2 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.

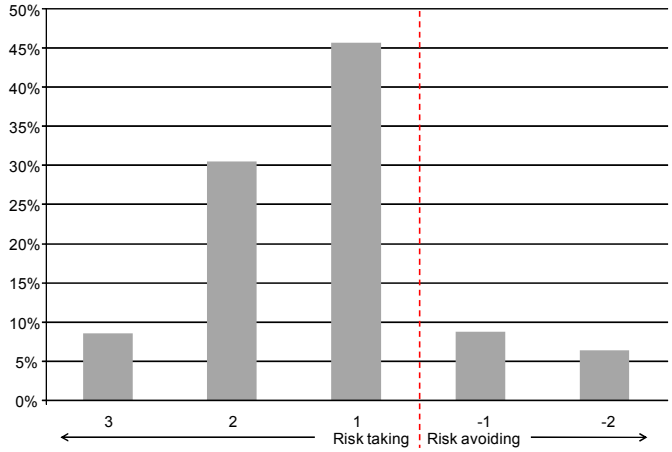

Fig. 2 Attitude towards security and privacy risk

Fig. 3 plots importance of privacy against overall satisfaction with protection of privacy. The size of the respective circles show the number of respondents, whereas the total- and the "risk avoiding"-respondents are differentiated. From a satisfaction level of 2 onwards respondents see an adequate protection. Thus 54% see a satisfactory level, whereas 32% see the desired level of privacy not granted, but thereof 3% don't care. The combination of an unsatisfactory privacy level combined with high importance figures, as depicted in the critical red rectangle, holds some negative potential towards refusal. Although 29% indicated their sentiment in this area, a distinct attitude towards risk taking eases this potential to only 5%, as 24% of all wireless communication equipment users are "risk takers" and presumably favor functionality over privacy 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, that 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% or even 5% of respondents unsatisfied with the overall technological situation.

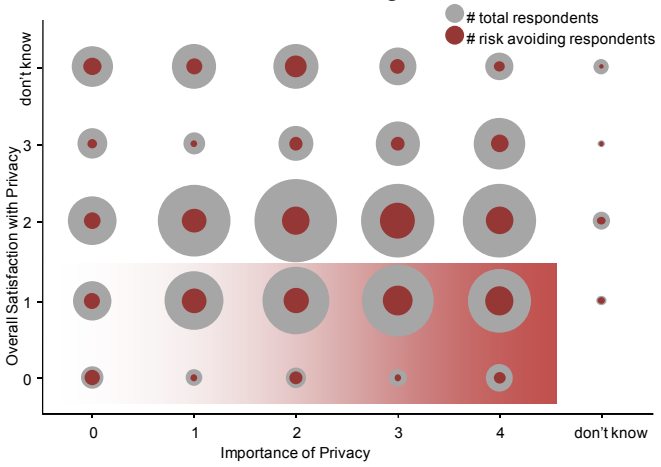

Fig. 3 Importance of privacy against overall satisfaction with privacy

- Radiation

As knowledge about the existence of certain technologies is a prerequisite for refusal it has been investigated if common wireless technologies are known. As shown in Fig. 4 many wireless technologies such as RFID, DECT and ZigBee are not known yet by all respondents. 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 consumerism picked up this technology, reprehending that these products constantly emit radiation, also in idle mode.

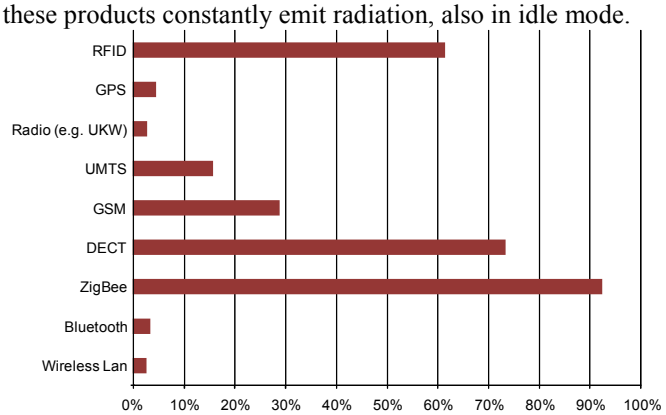

Fig. 4 Unknown wireless technologies, percentage of people who did not know about the existence of a certain technology

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.

Further, 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 shown in Fig. 5 and Fig. 6 show a tendency towards radiation avoidance. More functionality would not compensate for additional radiation for 61% and 48% would even accept less functionality for a reduction in radiation.

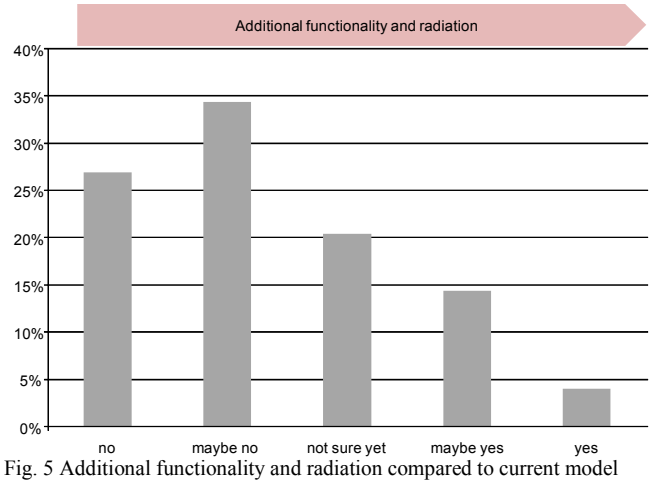

Fig. 5 Additional functionality and radiation compared to current model

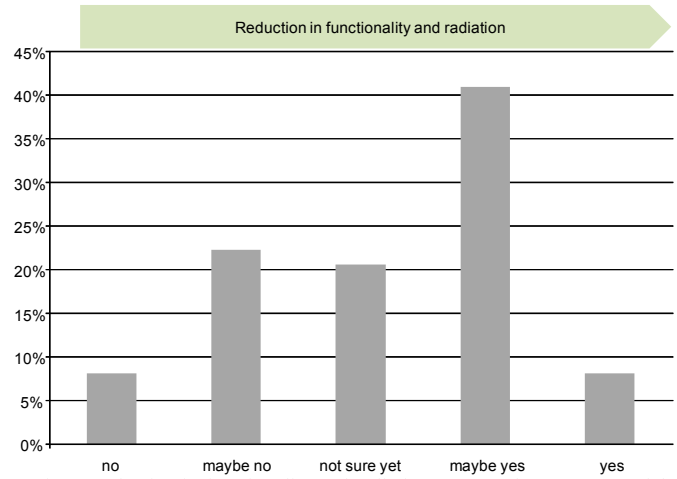

Fig. 6 Reduction in functionality and radiation compared to current model

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. Thus decisions are being made product functionality independent. Radiation is 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, due to high technology speed, 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 preference pattern.

- 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 the hand whilst talking, as this will allow the internal antenna to increase radio power up to 2W. Or by knowing how to protect wireless networks, that privacy can be ensured. First of all, one has to believe that these actions are effective. Fig. 7 and 8 show activity of respondents in self-protection, against their personal perception of effectiveness of self-protection.

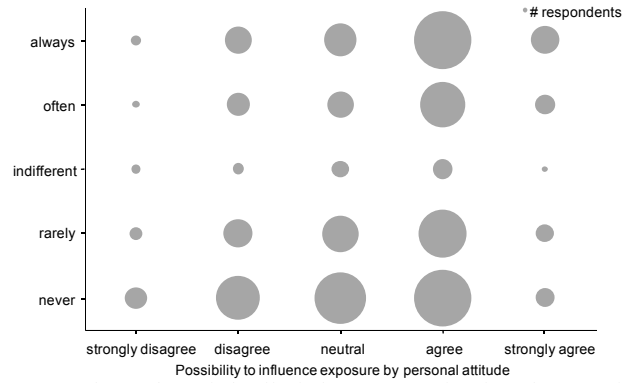

Fig. 7 Respondents who switch off wireless access points in order to avoid exposure, against their personal perception of effectiveness of self-protection

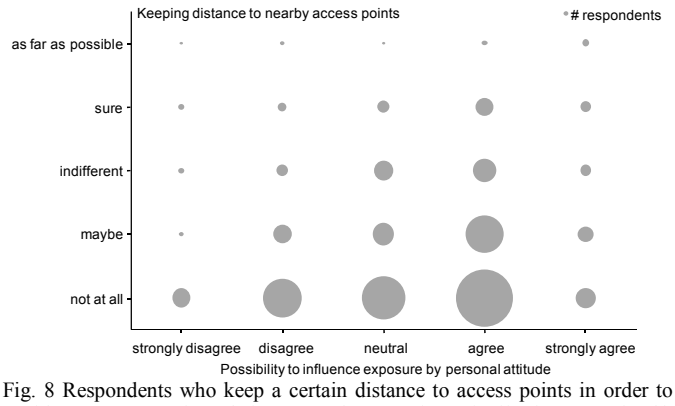

Fig. 8 Respondents who keep a certain distance to access points in order to avoid exposure, against their personal perception of effectiveness of self-protection

Whereas Fig. 7 shows the simple action of switching off wireless access points, Fig. 8 shows the more complex task of avoiding proximity to access points in everyday life. 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. The expected influence of belief in effectiveness of self-protection and activity in self-protection can't be seen in this data. Although

remarkable in this data is the accumulation 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. In Fig. 9 the perception of respondents' knowledge in the area of wireless communication is depicted. 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. Of the respondents, 45,8% indicated that they had the level of knowledge capable of implementing effective self-protection strategies.

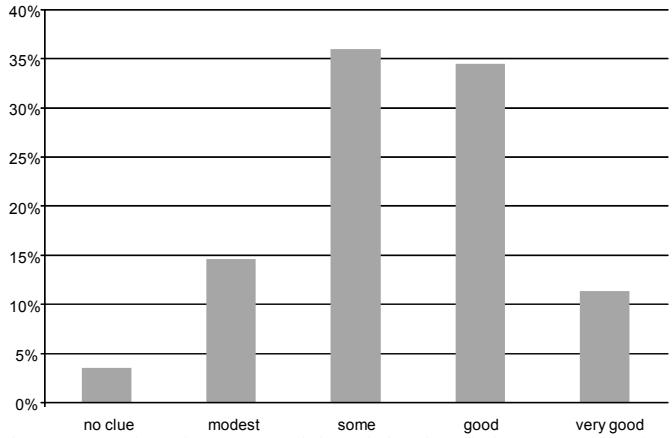

Fig. 9 Perception about personal knowledge in wireless communication technologies

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. As depicted in Fig. 10, media seems to be for the majority of respondents the most important information channel.

Confronted with news about negative side-effects, 60% of respondents who received the information described their reaction as surprised, worried or 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).

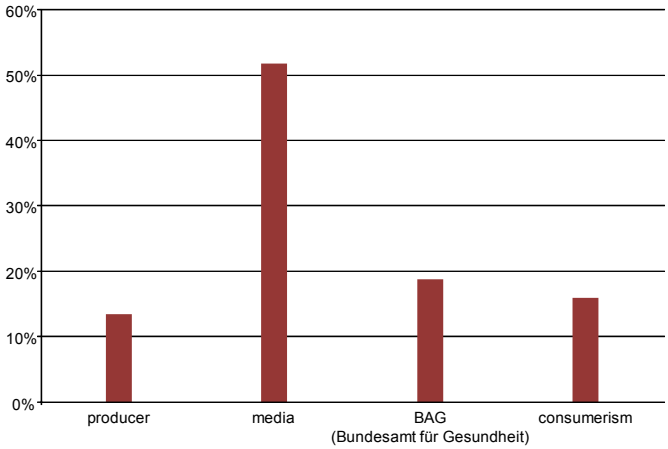

Fig. 10 Perception of most influencing information channel

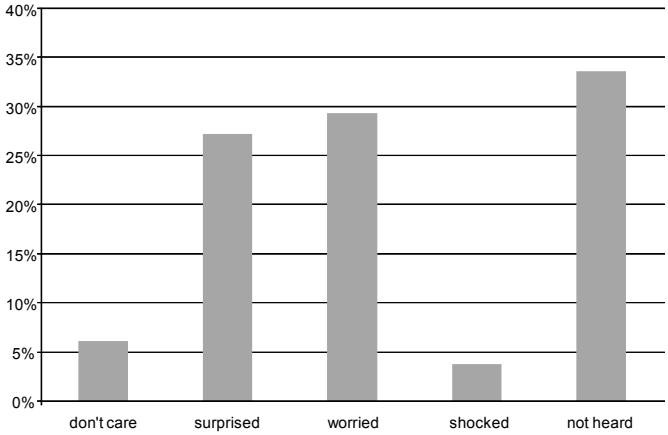

Fig. 11 Reaction on news about negative side-effects caused by radiation

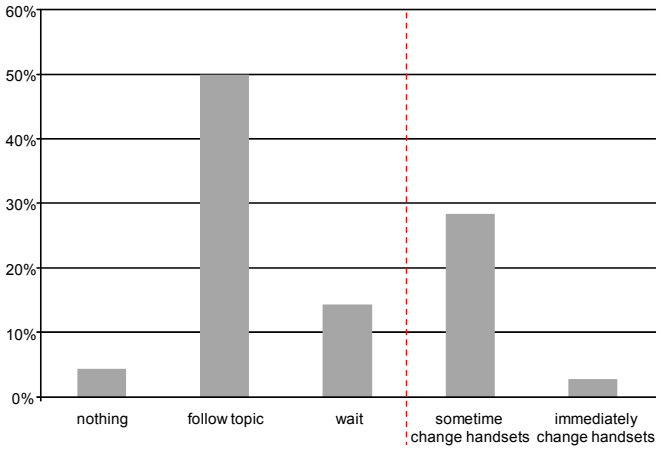

Fig. 12 Immediate action after scientifically assured side-effect

Hence ongoing use of existing equipment and technologies leads to a perceived confidence. Use of products over a certain period without any directly related negative side-effect, substitutes for absence of evidence of harmlessness. 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 antennas, whereas 64% don't see any exposure by radio antennas, as depicted in Fig 13 and 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 duration 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.

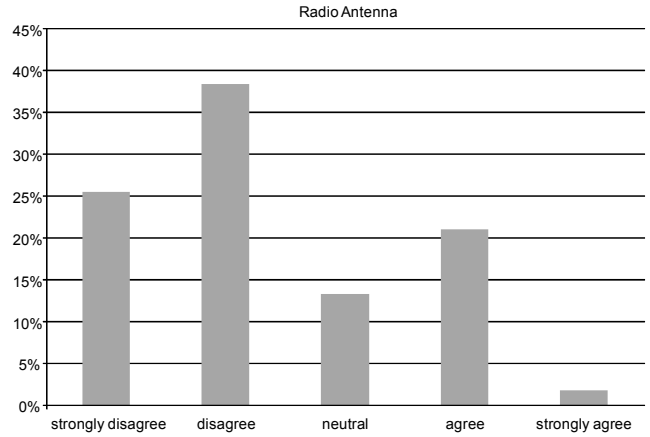

Fig. 13 Perception of dangerousness to health of radio antennas

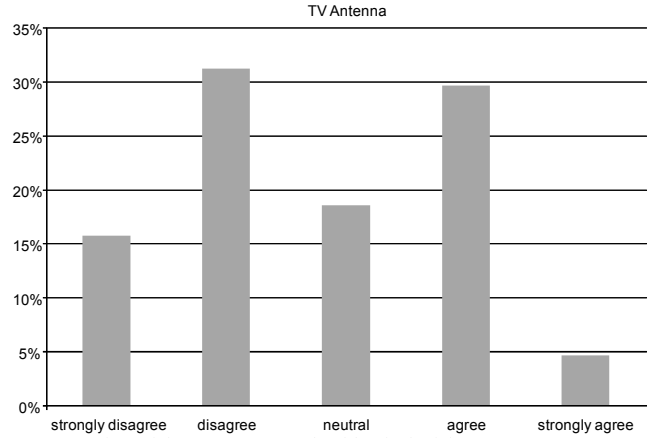

Fig. 14 Perception of dangerousness to health of television antennas

Another reason for no immediate or delayed action might be explained by the fact, that credibility of information channels is generally weak. As depicted in Fig. 15, among the different channels there seems to be a pattern in the categories of low, mediocre and increased credibility. This is led by consumerism and the BAG (Bundesamt für Gesundheit – federal bureau for health), whereas the laggards are the producers and the media. This result was expected, as consumerism and BAG strive for protection of consumer needs and would show a clear tendency towards credible information channels.

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.

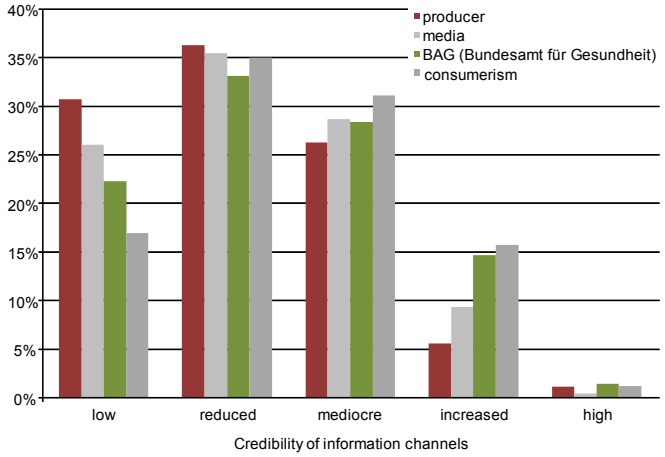

Fig. 15 Credibility differs among formation channels

• Negative externalities and personal benefit

It is to be determined whether respondents more actively try to avoid base station radiation or handset radiation. Radiation is emitted to others not directly profiting from a specific base station, whereas personal handsets have utilitarian value. Hence, negative externalities to a third party are only expected from base stations. Fig. 16 highlights which source of radiation exposure is more readily accepted. It first shows that there seems to be a recognizable correspondence between avoidance of base station radiation and handset radiation. Secondly, there seems to be a tendency towards disinterest of radiation as such, as 42% show a consistent comportment of never or rarely avoiding as depicted in the lower left quadrant in Fig.16. Only 10% show a consistent avoiding-attitude as seen in the upper right quadrant in Fig. 16. The rest shows semi-consistent attitudes as it differs between base stations and handsets. Third it is distinct, that the semi-consistent-group of "handset-radiation-avoiders" as depicted in the lower right quadrant in Fig. 16 holds with 17% more respondents than the upper left one with only 4%.

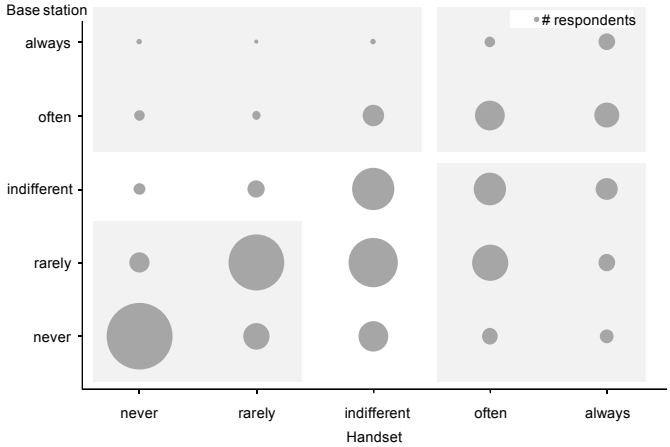

Fig. 16 Avoiders of radiation emitted by base stations and handsets

Following these results it seems that 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 hinder 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 is to be set equally to 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 easiness of this task and not in considerations about distribution of profits and burdens. Hence negative externalities don't seem to play an important role for refusal of a technology in this setup. Radiation is considered source independently. An augmentation of the set up would be the attitude towards negative externalities by base stations of nearby residents compared to their attitude to avoid handset radiation. In this case negative externalities would be augmented drastically without any additional perceived utility.

- Technology speed

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

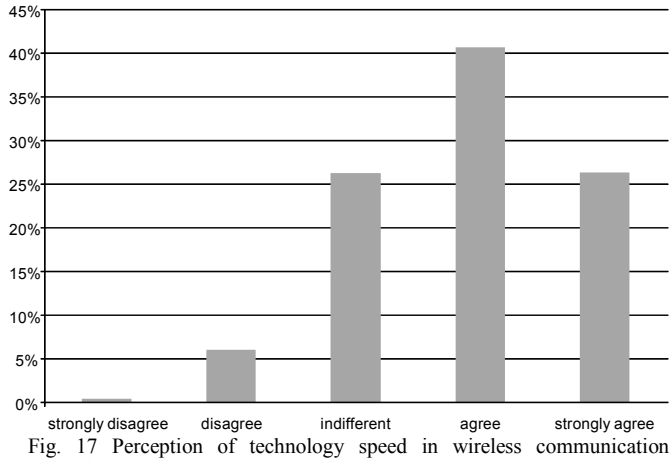

Fig. 17 Perception of technology speed in wireless communication technologies

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 as shown in Fig. 17 and 18. Regulation is still lagging due to absence of scientific evidence. This enforces the receptiveness for any information what so ever as no assured facts are available. In this unsettled period public opinion is difficult to foresee and easy to influence by opinion leaders or even by media.

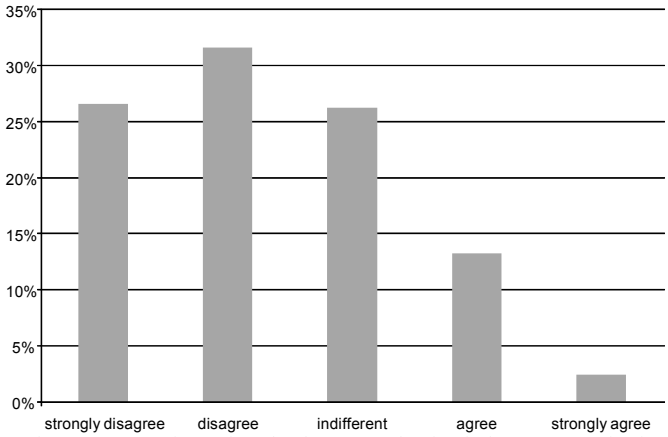

Fig. 18 Perception of technology speed of wireless communication technologies outpacing absorptive capacity

IV. Discussion

The sole figure of 10,6% return rate shows a very high sensitivity to this survey topic. Although not yet indicating any trend as such, awareness to these issues seems to be very 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, although they attribute importance to it. 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 sentiment is going to develop as opinion leaders might play a crucial role. Possibly they are also among this 29% of disappointed 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 very limited extent give back control over radiation to individuals. But means have to be simple, as knowledge about wireless communication technologies is not always rock solid and motivation sinks with complexity of actions involved.

Scientific knowledge about radiation is generally weak; therefore information channels have low credibility in this topic, although consumerism and BAG are edging a little higher. Thus, although media get high influencing figures, attributed credibility remains low. News about wireless technologies clearly influences respondent's sentiment. But direct actions are not to be expected, as changes in equipment always entail additional spending. Whereas ongoing usage of long used products does not pose immediate but long-term effects. But it is not to be neglected that regulators normally decide over third party's equipment. Additional breakthrough-information may very well influence public opinion, whereas pieces of the information puzzle as such, are nearly neglected.

Respondents take action where it is feasible, 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 sentiment in the nearby neighborhood of a base station might result in different results. Thus refusal against wireless networks might start in small nucleus in vicinity of base stations. All in all current sentiment towards radiation of wireless networks does not reach high awareness in general.

By the perception of respondents, technology seems to develop at high speed though in general consumers manage to keep pace with this evolution. But regulation is still lagging behind; this can be seen as prescriptive 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 as precise values are unknown.

V. Conclusion

At the advent of first indications of a trend towards acceptance or refusal, opinions will be mad 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 sufficiently available. 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 favoring ease of use of products. Because technology seems to be developing at high speed, break-through scientific information or strong opinion leaders would be needed in order to substantially influence public opinion.

In a situation where companies are tied up to certain technologies either by investments in facilities or in knowledge and jiggling public opinion accompanied by high public visibility are present, cautious and long-sighted technology monitoring and planning is needed. Thus a systematic surveillance of weak signals is advised for companies involved in wireless technologies.

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