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Body-loss for Popular Thin Smart Phones

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***Abstract*—In this contribution, an investigation of the radio performance of recent popular phones has been done. The antenna performance has been evaluated with the newly agreed phantom head-hand measurements of the mobile antenna efficiency. It has been observed that the newer generation thin smart phones have worse performance than the classical phones and more surprisingly there is a loss in performance between generation of the same brand of smart phone. The effect of the performance variation between phones has been illustrated by calculating the coverage area for the voice service for Denmark with data from all mobile operators for the best and worst performing ones.**

I. Introduction

The performance of the radio link is an important aspect in the planning stage of any wireless network. The receiver sensitivity is an essential figure in the link budget and the correct value of the realistic received sensitivity must be found. For mobile phones, the ability to receive and transmit signals efficiently is crucial for the quality of the communication and for the cell planning of the network operators.

It has been shown in previous studies that the performance of the mobile phone antenna is significantly affected by the presence of the user's lossy tissue ([1] and [2]). Furthermore, the level of degradation can be very different from one user to another or from one phone to another [3]. The way the user handles the phone as well as the antenna type are the contributing factors for this difference [4].

In some sparsely populated areas, one of the problems is the lack of basic telephony service not to mention wireless data service. Lately a strong pressure from citizens on the local elected political representatives to guaranty everywhere at least outdoor telephone coverage for emergency services. Due to the large variation in mobile performance, there is a strong motivation for having up to date and realistic coverage maps for telecommunication governing bodies.

As the mobile phone industry progresses and with the evolution towards thinner phones, the size and placement constraints for the antennas are more stringent [5]. Furthermore, consideration for the user interaction is an important part in the antenna design. For practical limitations such as cost and development time, it is common practice to assess the transceiver's quality by measuring the total radiated power (TRP) and the total isotropic sensitivity (TIS). These metrics are measured with the user's presence being mimicked by a phantom - e.g. the SAM and hand phantom with the test procedure involving usually only one certain type of grip, as defined in [7] and [8]. It has been shown in [6] that the TRP and TIS values are very robust to errors due to incorrect placement of the device on the SAM phantom thus a high measurement repeatability is obtained. The standardization for testing and measuring phones was introduced to ensure uniformity in results between different laboratories.

In this paper, the radio performance of the latest generations of the most popular smart phones as well as the more classical phones is investigated. It is well know that the different users will affect the phones in different ways due to different factors like the way they hold the phone or the shape and size of the hands etc. For this work, we are not focusing on this aspect, which has been covered by the literature, rather we are looking at the differences between phones. In addition, when we are assessing coverage we are concerned by voice service not data service therefore, capacity is not considered. The paper starts with a description of the methodology, continues with the measurement results and the recently calculated coverage maps for Denmark. The final section concludes on the work.

Fig. 1. The head and hands phantoms, the PDA hand on the left and the monoblock hand on the right.

II. Methodology

The phones selected for this study have been chosen from the list of the top 10 most sold phones by the four Danish mo-

TABLE I
THE MEASURED RESULTS FOR THE SAM AND HAND PHANTOM.

Band	GSM 900		GSM 1800		UMTS Band VIII		UMTS Band I	
Setup	TRP (dBm)	TIS (dBm)	TRP (dBm)	TIS (dBm)	TRP (dBm)	TIS (dBm)	TRP (dBm)	TIS (dBm)
Iphone 4	18,2	-95,7	20,7	-99,3	9,9	-98,4	12,1	-99,7
Iphone 4S	19	-93,3	18,9	-94,9	10,3	-101,6	10,7	-98,6
Iphone 5	16,9	-88,8	14,4	-92,0	7,6	-98,2	6,1	-97,5
Samsung S2	16,9	-93,2	17,7	-99,8	7,6	-94,7	12	-99,9
Samsung S3	16,6	-89,9	21,1	-101	7,2	-95,3	13	-104
HTC Wildfire S	20,1	-93,5	20,6	-101	9,8	-94,1	13,1	-100,1
Nokia 1800	16,7	-96	17,1	-95,9	N/A	N/A	N/A	N/A
Nokia C1	18,7	-93,9	16,6	-95,8	N/A	N/A	N/A	N/A
Nokia C2	19,5	-93,1	21,4	-99,9	9,2	-95,2	12,4	-98,8
Nokia C3	16,7	-93,2	16,8	-96,9	6,6	-94,1	9,8	-99,6

bile operators in 2011 [10] and the two expected most popular models in 2012. The selection contains six smart phones with the format PDA and four traditional mobile phones with the candy-bar shape. There is considerable shape diversity as well as a variety of different technology generations between the chosen devices. This should ensure a broader set of results. The phones have not been modified in any way in order to avoid altering the results.

The measurements have been done according to CTIA's testplan 3.2 [8] using the built-in capabilities of the networks, the so-called active measurements. Using the Satimo Starlab [9] together with the base-station emulator CMU200 from Rodhe & Schwarz in a shielded anechoic chamber, the TRP and TIS have been measured with the phantom head and hand. The Starlab and CMU200 are controlled through a PC which is also used for logging the data.

The measurement procedure was done according to the specification of [8]. The hand and head phantoms are manufactured according to the specifications same specifications. Only one type of grip has been used in the measurement campaign, as specified by the test plan, the PDA grip for the smart phone and the monoblock grip for the smaller candy-bar phones which are illustrated in figure 1. To ensure a realistic placement of the phone, the standard specifies that a six degree spacer must be inserted between the phone and the phantom's cheek, as illustrated in figure 3.

The radius of the measurement ring is small compared to the wavelength, as it can be seen in figure 2. For a near-filed measurement setup such as this one, the reflection from the ring and from the probes are considerable. Although great consideration has been given to minimize this effect, still it is affecting the measurement accuracy. For the Starlab, it is specified to be ± 1.8 dB.

The Starlab has 15 bidirectional probes mounted on a supporting ring which can be used as receivers or transmitters, depending on the measurement type. There is also a mast antenna for keeping the connection with the mobile during measurement which is shown in figure 4. The propagation losses from the device under test (DUT) to the probes as well as the internal losses in the Starlab are calibrated out by measuring a reference antenna.

The mean effective gain (MEG) is a metric more suitable for evaluating mobile phones in many realistic environments [12]. It incorporates the antenna gain pattern and the propagation characteristics of the channel. However, for this contribution only the TRP and TIS have been assessed. The TIS metric is the total antenna efficiency including mismatch and loading impedance. It does not include the influence from the environment which call for a MEG validation which is not yet agreed upon in the test plans .

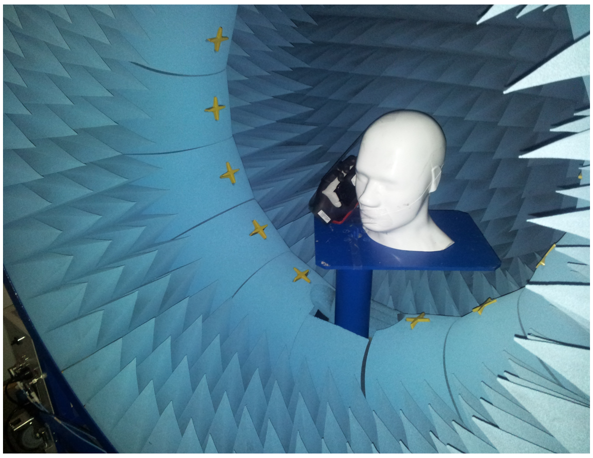

Fig. 2. Illustration of the SAM and hand phantom placement in the Starlab chamber for obtaining the TRP and TIS results.

Fig. 3. Close up of the phone's placement on the phantom's cheek.

The TRP metric evaluates the amount of energy that a phone can radiate into space. The DUT is set to transmit with maximum power which then is measured with the probes and recorded. These values are then averaged over the spherical coordinates. There is a part of the measurement that is missing which corresponds to the area occupied by the mast and it is omitted. The TRP measurements have been done with 15 degrees steeping both in azimuth and elevation whereas the TIS measurements, because they are more time consuming have been done with 30 degrees steeping.

For each of the ten phones, four band have been measured (GSM 900 , GSM 1800, UMTS band VIII and I) and for each band only the middle channel has been included in the results. The variation across the band is maximum around 1 dB thus the complete results have not been included for the sake of brevity .

III. Results and Discussions

The results of the active measurement using the phantom head and hand are shown in Table I. They indicate that the phones are severely affected by the user's presence, around 10 to 14 dB's of added loss. For the GSM 900 the power rating at the PA output is 33 dBm . Obviously, there is a significant amount of power lost due to the low antenna efficiency. The phones are more affected at the lower frequencies then at the higher bands because at low frequencies the whole ground plane of the printed circuit board (PCB) is used for radiation. However, the loss can be minimized by reducing the current density in the close proximity of the user's tissue, as shown by the 4 dB difference in loss between the best and the worst phone.

The Iphone 4 antenna has been discussed extensively thought literature and in the press because of the so called "death grip" which is explained in [5]. The results shown here are for the default CTIA defined grip which avoids this issue. For this reason the results look comparable with other phones. If the iphone 4 is located just slightly different in the hand the resultant loss at low band can change up to more than 30 dB - no other phones have been seen to change performance to such a degree and for such small change of the hand.

In areas with coverage problems e.g. at the cell edge, the sensitivity is essential to keep the connection or to be able to make a call and, if possible, the operator will most likely select the low frequency band. An unsettling trend can be observed when the different generations of phones are compared, the Iphone's and the two Samsungs Galaxy. The transceiver quality at the low band of GSM is decreasing from one generation to the other despite the fact that the size of the phone is increasing.

There is a trend among phone manufactures to have all metallic casings. Two of the worst performing phones, the Iphone 5 and Nokia C3, have this feature. Although from a design point of view it is appealing, from an antenna perspective this is disastrous because it is know that an equivalent current source cannot radiate efficiently in the close proximity of an electric conductor.

A recent report [11] published by the Danish Business Minister(Erhvervsstyrelsen) based on the TIS numbers reported

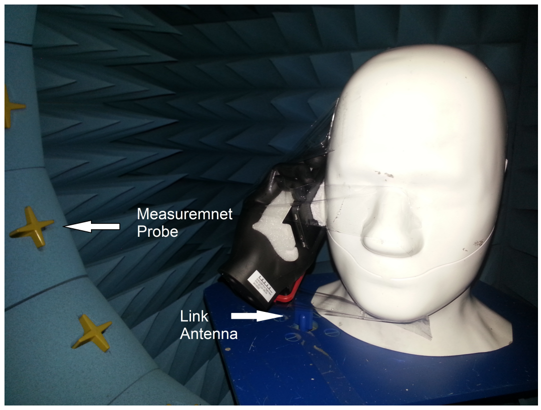

Fig. 4. Close up of the phantom's positioning in the Starlab with the probes and link antenna highlighted .

here and with the electric fieldstrength reported by the four mobile operators offering services in Denmark is showing the impact of antenna efficiency on the voice service coverage area. To calculate the coverage maps, some assumption were made and are presented in the rest of the section.

If it is assumed that the incoming power to the mobile phone is arriving equally likely from all directions and both polarizations, as is commonly the assumption taken in mobile communication, then the following equation is the relation between TIS and the Root Mean Square (RMS) value of the magnitude of the electric fieldstrength:

$$|E| = \frac{\sqrt{4\pi\eta TIS}}{\lambda} \qquad (1)$$

where, $|E|$ represents the RMS value of the magnitude of the electric fieldstrength, η is the free-space impedance and λ is the wavelength.

The needed minimum field strength which can be calculated directly from the TIS values apply only under the circumstances where the phone where tested, i.e. a static channel. To account for the mobile channel and the variations over a large area (tens of wavelengths say 10 x 10 meters) and the spread among users etc the following margins are included:

- Fast-fading - here defined as the margin needed from the specified nominal sensitivity to the sensitivity needed to pass all fading tests. A typical value for GSM is some 6 dB and for UMTS is some 2 dB.

- Slow-fading - The standard deviation of the slow fading is reported to be some 8 dB at 900 MHz and some 9 dB at 1800 and 2100 MHz [13].

- Spread among phone users - different persons using the exact same phone results in rather different bodyloss. This spread is reported to give a spread of some 10 dB [3] mainly due to different ways of holding the phone. To ensure most users to be able to use a given mobile phone a margin of some 5 dB should be included.

- Mean Effective Gain (MEG)-in a real environment the orientation of the user do impact the ability to receive a signal from the base station. This is not included in the TIS value as TIS assumes that all directions can

TABLE II
MARGIN TO BE ADDED TO THE MINIMUM AVERAGE ELECTRICAL FIELD STRENGTH LIMIT FOR EACH SYSTEM AND FREQUENCY BANDS.

Mobile System	Frequency Band	Additional margin [dB]
GSM	900	22 dB
GSM	1800	23 dB
UMTS	900	18 dB
UMTS	2100	19 dB

receive equally well. This is not the case and especially at more rural areas where coverage can be a problem the difference between MEG and TIS is the largest [12]. A margin of some dB should be included to ensure that a call can be completed even when the person is turning around during the call.

Under these assumption coverage maps for voice service have been calculated using the TIS from the best and the worst one performing phone(the "good phone" and the "bad phone"). The study found specifically that in 477 out of 586 postcodes there is a geographical outdoor coverage greater than 99 percent with the "good phone". However, in only 210 out of 586 postcodes the "bad phone" could offer same coverage. The detailed maps are shown in figure 5 and 6.

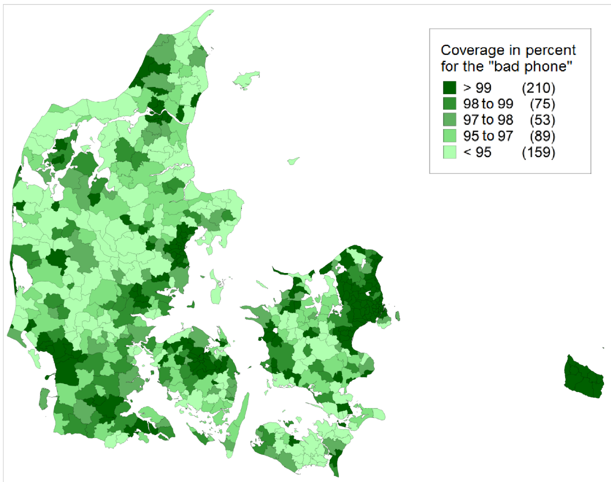

Fig. 5. Outdoor mobile coverage for all companies, calculated for a mobile phone with not so good receiver properties at zip code level[11].

IV. CONCLUSIONS AND FURTHER WORK

In this work, the transceiver quality has been evaluated for some of the most popular phones. From the measured sensitivity of the phones next to the head and held by a hand as specified in the CTIA testplan, there is indication that the bodyloss increases for the smart phones.

In addition, for two of the very popular new models, the results show even worse performance than see earlier. This will have a big impact on the networks where 1 dB of extra loss in the phone translates into 12-16% more base-stations needed to provide the same coverage [14]. The network operators need to be aware that there is a big spread in radio performance between phones so they can plan accordingly. The effect of a couple of dB in antenna efficiency has significant effect in terms of coverage area, as illustrated in [11]. To conclude on the latest generation of the Galaxy and iPhone with respect to the last generation a additional loss of some 5 dB requires more or less a doubling of the mobile base-stations to give the same coverage.

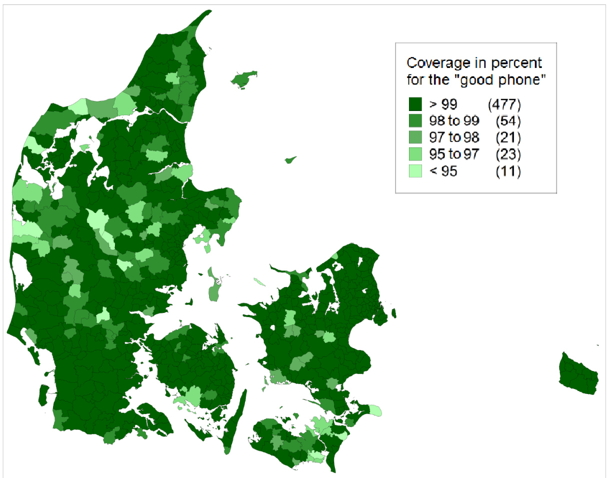

Fig. 6. Outdoor mobile coverage for all companies, calculated for a mobile phone with a good receiver properties at zip code level[11].

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