Radio frequency radiation measurement from mobile base station at capital of Yemen Sana’a

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Abstract: Electromagnetic radiation consists of waves of electric and magnetic energy moving together (i.e., radiating) through space at the speed of light. Taken together, all forms of electromagnetic energy are referred to as the electromagnetic "spectrum". By the way, in Yemen nobody asks or interested about public health concerned Radio Frequency Radiation (RFR) (invisible pollution) emitted from mobile base stations even government presented by the Ministry of Telecommunication and Information Technology. We can’t imagine that this related ministry doesn’t have any radio frequency measurement equipment. WHO branch Yemen, Sana’a doesn’t interested too for evaluating health risk accused by RFR. Mobile phone sector in Yemen increased dramatically during last ten years where you can see everywhere in Yemen randomly Base Transmitted Stations (BTS) antennas. The aim of this paper is to measure and study the intensity of Electromagnetic Radiation (EMR) known as the power density (W/m2) emitted from mobile phone base stations operated by four mobile networks in Sana’a Yemen. The power density of spot measurement at different distances of transmitted antennas of base stations are measured. Several measurements were done at schools, hospitals, universities, and main squares in Sana’a. We obtained several results that we compared it with international standards.

Key words: Invisible pollution; radio frequency fields; spot radiation measurements; public health; measurement equipment’s.

1. Introduction

Yemen is one of the least developed countries in the Middle East, situated between 13N-16N latitude and 43.2 – 53.2 longitude at the south west of Asia. It is surrounded by the Red Sea from the west and by Arab Sea and Indian Ocean, from the south. GSM mobile services started in Yemen in 2001. The two systems are used GSM and the CDMA1. Yemen has a population of some 24 million, and has three GSM operators: MTN branch - Yemen, Sabafon, whose MTN and Sabafon have similar market shares, and Y company, which entered the market in about 2007, failed to gain traction. But another mobile phone operator as Yemen Mobile, which is 55% owned by the state incumbent Yemen Telecom (YT) and uses a CDMA system, is a significant player in the market, with a similar to market share to MTN and Sabafon.

According to Dubai-based research and consultancy firm Delta Partners, the market share of the four mobile operators in 2009 stood at: 37% for MTN; 31% for Yemen Mobile; and 29% for Sabafon, while Y-Tel trailed on 5%. Delta Partners forecasts that these four operators will achieve markets shares of 38%, 30%, 24% and 8% respectively, by 2014. Total amount of base stations in Yemen arrived until 31 December 2012 of 3040 BTS. Due to the dense population in Yemen, the network of base station antennas is really visible and the number of base
stations is continuously growing especially in the downtown and heavy traffic areas, and therefore there is a big concern about safety from EM-fields. An overview of the existing networks is given in Table 1.

Table 1: Mobile phone network systems and operators in Yemen

<table>
<thead>
<tr>
<th>Standard</th>
<th>operators</th>
<th>operated from</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSM 900 &amp; 1800</td>
<td>Sabafon Company</td>
<td>2001</td>
</tr>
<tr>
<td>GSM 900 &amp; 1800</td>
<td>MTN Company</td>
<td>2001</td>
</tr>
<tr>
<td>GSM 900</td>
<td>Y Company</td>
<td>2007</td>
</tr>
<tr>
<td>CDMA 1</td>
<td>Yemen Mobile Company</td>
<td>2004</td>
</tr>
</tbody>
</table>

2. Scope of study

1. Select and measure of 256 different sites operated by four mobile operators: three GSM and one CDMA. These measurements don’t take into account the traffic and can’t allow a precise analysis.
2. Choice specific location as schools, hospitals, universities, and others high traffic areas. For each case, the maximum level of electric field has been searched in the public zone.
3. All operators of mobile phones in Yemen don’t cooperate with the researchers.
4. Refuse all operators, WHO and Ministry of Telecommunication, to buy any measurement tools.
5. Collect and study main reference standards related to RFR.

3. Related work

The Agence Nationale des Fréquences (ANFR) of France sent two experts to Yemen for two weeks from March 2 to March 16, 2007, in order to share their experience and know-how regarding the in situ electromagnetic fields (EMF) measurement procedure. This assignment gave the opportunity to make measurements between 100 kHz and 3 GHz, and to train some Yemeni engineers on the handling of measurement equipment’s. The assignment result in a report was to be provided to the authorities of Yemen. But this report put in the shelf and they forget it until now a days.

One seminar about RFR is organized in Sana’a during the period 28 to 30 April, 2007 to illustrate and discuss RFR, 14 speakers presented their own work about this invisible pollution. Unfortunately, the Ministry of Telecommunication and mobile networks operators in Yemen used the work presented in References. and this meeting was only for propaganda. Indeed, much work has been done in international literature toward measuring invisible pollution (radio frequency radiation), most research reported, such as presented in.

3.1 Measurement results and discussion

Several measurements have been done to measure electromagnetic field strength at difference locations in the capital, Sana’a. Some of these measurements results are presented in Table 2. Its measurements are
conducted at different sites in Sana'a such as locations from Al-Tahreer area to AL-Mesbahi tunnel. The highest readings are taken for every site at all bands. For GSM900, maximum RF radiation level is in Al-Tahreer area (city center). The power density in this location is $7513\mu W/m^2$ at frequency 948.8 MHz. For GSM1800, maximum RF radiation level is in Al-Tahreer area also. The power density in this location is $2910\mu W/m^2$ at frequency 1806 MHz. For CDMA, also maximum RF radiation level is in Al-Tahreer area. The power density in this location is $4219\mu W/m^2$ at frequency 877 MHz.

### Table 2: Measurements at different sites in Sana’a (inc. Al-Tahreer, and AL-Mesbahi tunnel)

<table>
<thead>
<tr>
<th>#</th>
<th>Location</th>
<th>Type of site</th>
<th>Freq(MHz) at Pmax</th>
<th>Max PdBm</th>
<th>Max P(µW/m²)</th>
<th>Max E (V/m)</th>
<th>ICNIRP (%)</th>
<th>Salz1 (%)</th>
<th>Salz2 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Al-Tahreer</td>
<td>GSM900</td>
<td>948.8</td>
<td>-12</td>
<td>7513</td>
<td>1.683</td>
<td>3.97</td>
<td>751.39</td>
<td>overflow</td>
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<tr>
<td></td>
<td></td>
<td>GSM1800</td>
<td>1806</td>
<td>-22</td>
<td>2910</td>
<td>1.048</td>
<td>1.79</td>
<td>291.76</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CDMA</td>
<td>877</td>
<td>-14</td>
<td>4219</td>
<td>1.261</td>
<td>3.09</td>
<td>421.94</td>
<td>***</td>
</tr>
<tr>
<td>S2</td>
<td>Al-ka'a'a place</td>
<td>GSM900</td>
<td>947.2</td>
<td>-14</td>
<td>5550</td>
<td>1.446</td>
<td>3.41</td>
<td>555.04</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GSM1800</td>
<td>1877</td>
<td>-41</td>
<td>36.64</td>
<td>0.118</td>
<td>0.19</td>
<td>3.66</td>
<td>366.45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CDMA</td>
<td>877</td>
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<td>52.14</td>
<td>0.140</td>
<td>0.34</td>
<td>5.21</td>
<td>521.43</td>
</tr>
<tr>
<td>S3</td>
<td>Old Sana'a AL-Yemen gate</td>
<td>GSM900</td>
<td>937.6</td>
<td>-22</td>
<td>753.90</td>
<td>0.533</td>
<td>1.26</td>
<td>75.39</td>
<td>***</td>
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<tr>
<td></td>
<td></td>
<td>GSM1800</td>
<td>1875</td>
<td>-46</td>
<td>11.95</td>
<td>0.067</td>
<td>0.11</td>
<td>1.19</td>
<td>119.50</td>
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<td></td>
<td></td>
<td>CDMA</td>
<td>977.4</td>
<td>-37</td>
<td>22.90</td>
<td>0.093</td>
<td>0.22</td>
<td>2.29</td>
<td>229.01</td>
</tr>
<tr>
<td>S4</td>
<td>Old Sana'a in front of the large mosque farm</td>
<td>GSM900</td>
<td>952.8</td>
<td>-47</td>
<td>2.49</td>
<td>0.031</td>
<td>0.07</td>
<td>0.24</td>
<td>24.97</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GSM1800</td>
<td>1810</td>
<td>-61</td>
<td>0.3253</td>
<td>0.011</td>
<td>0.01</td>
<td>0.03</td>
<td>3.25</td>
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<tr>
<td></td>
<td></td>
<td>CDMA</td>
<td>876.8</td>
<td>-16</td>
<td>2.930</td>
<td>1.051</td>
<td>2.58</td>
<td>293.04</td>
<td>***</td>
</tr>
<tr>
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<td>Tele-yemen</td>
<td>GSM900</td>
<td>948.8</td>
<td>-41</td>
<td>10.17</td>
<td>0.062</td>
<td>0.14</td>
<td>1.01</td>
<td>101.72</td>
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<td></td>
<td></td>
<td>GSM1800</td>
<td>1826</td>
<td>-40</td>
<td>22.9</td>
<td>0.093</td>
<td>0.158</td>
<td>2.29</td>
<td>229.63</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CDMA</td>
<td>877</td>
<td>-20</td>
<td>10.66</td>
<td>0.634</td>
<td>1.556</td>
<td>106.76</td>
<td>***</td>
</tr>
<tr>
<td>S6</td>
<td>New university (near post office)</td>
<td>GSM900</td>
<td>944.8</td>
<td>-24</td>
<td>507.118</td>
<td>0.437</td>
<td>1.03</td>
<td>50.71</td>
<td>***</td>
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<tr>
<td></td>
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<td>GSM1800</td>
<td>1819</td>
<td>-36</td>
<td>106.29</td>
<td>0.200</td>
<td>0.34</td>
<td>16.16</td>
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<td></td>
<td></td>
<td>CDMA</td>
<td>877</td>
<td>-20</td>
<td>11.40</td>
<td>0.658</td>
<td>1.61</td>
<td>1.14</td>
<td>***</td>
</tr>
<tr>
<td>S7</td>
<td>Shomila area-Next to Post Office</td>
<td>GSM900</td>
<td>938.4</td>
<td>-23</td>
<td>615.19</td>
<td>0.481</td>
<td>1.14</td>
<td>61.52</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>GSM1800</td>
<td>1811</td>
<td>-38</td>
<td>102.9</td>
<td>0.196</td>
<td>0.22</td>
<td>10.29</td>
<td>102.9</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>880</td>
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<td>890.37</td>
<td>0.579</td>
<td>1.41</td>
<td>89.03</td>
<td>***</td>
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<td>S8</td>
<td>Hadaa Area Front of Al-wohda club</td>
<td>GSM900</td>
<td>948.8</td>
<td>-18</td>
<td>1980</td>
<td>0.865</td>
<td>2.04</td>
<td>196.82</td>
<td>***</td>
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<tr>
<td></td>
<td></td>
<td>GSM1800</td>
<td>1821</td>
<td>-40</td>
<td>45.25</td>
<td>0.131</td>
<td>0.22</td>
<td>4.52</td>
<td>452.58</td>
</tr>
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<td></td>
<td></td>
<td>CDMA</td>
<td>876.6</td>
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<td>28.80</td>
<td>0.104</td>
<td>0.256</td>
<td>2.88</td>
<td>288.01</td>
</tr>
<tr>
<td>S9</td>
<td>The Airport</td>
<td>GSM900</td>
<td>935</td>
<td>-33</td>
<td>64.77</td>
<td>0.156</td>
<td>0.371</td>
<td>6.477</td>
<td>647.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GSM1800</td>
<td>1830</td>
<td>-61</td>
<td>0.985</td>
<td>0.019</td>
<td>0.032</td>
<td>0.0984</td>
<td>9.85</td>
</tr>
</tbody>
</table>

Figure 1 demonstrates power density with $\mu W/cm^2$ for several sites at GSM900, GSM1800 and CDMA. The graph illustrates all the sites with its readings in $\mu W/cm^2$. At GSM900, the highest readings are in Asser round and AL-Da'iry line. The power density in these locations are $0.829\mu W/cm^2$ and $0.946\mu W/cm^2$. At GSM1800, maximum measurement is nearby Hail Telecom Switch. The power density in this location
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is 0.0198µW/cm². At CDMA, maximum RF radiation levels are nearby Hail Telecom Switch and Libyan city area. The power density in these locations are 0.908µW/cm² and 0.903µW/cm².

Figure 1: Power density for several sites at GSM900, GSM1800, and CDMA in Sana’a.

Figure 2 illustrates the power density µW/cm² with the frequency MHz. At GSM900, the highest reading is 0.9462µW/cm² at frequency 955.2MHz. For GSM1800, the highest reading is 0.291µW/cm² at frequency 1806MHz. For CDMA, the highest reading is 0.908µW/cm² at frequency 877MHz.

Figure 2: Power density levels that measured at GSM900, GSM1800, and CDMA.

For GSM1800, maximum RF radiation level is in Al-Tahreer area as demonstrated in Fig. 3. The power density in this location is 2910 µW/m² (E=1.048 V/m). This value represents 0.032 % of ICNIRP limit (9W/m²) that is lesser than this limit by 3093 times. It stands for 2.9 % of Italy limit (which is 0.1W/m²), in other words the power density in this location is lesser than Italy limit by 34.36 times. It corresponds to 291% of Salzburg precautionary value limit (which is 1000 µW/m²), that is the power density in this location is larger than Salzburg by 2.91times (this indicate excess of the exposure limit). Therefore, the reading in Al-Tahreer Area is the highest value taken for GSM1800, which is specifically at frequency 1806MHz that belongs to Sabafon Company.
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Figure 3: Power density for several sites at GSM1800 from maximum to minimum.

At CDMA, the maximum level is in vicinity of Hail Telecom site. The power density in this location is 9080 µW/m² (E=1.85 V/m). This value represents 0.21% of ICNIRP limit (4.38 W/m²) that is lesser than this limit by 482.38 times. It represents 9.08% of Italy limit (which is 0.1W/m²) too. In other words, the power density in this location is lesser than Italy limit by 11 times. And it represent, 908% of Salzburg precautionary value limit (which is 1000 µW/m²), that is the power density in this location and is larger than Salzburg by 9.08 times (this indicate excess of the exposure limit). Thus, the reading in Hail Area is the highest value taken for CDMA which is specifically at frequency 877MHz as demonstrated in Fig. 4.

Figure 4: Power density for several sites for CDMA from maximum to minimum.

4. Measurement nearby some hospitals and schools in Sana’a

The measurements are conducted at different sites nearby some hospitals and schools in Sana’a, measurements are displayed in Table 3 and the graph is illustrated in Fig. 5 and Fig. 6.
### Table 3: Measurements nearby some hospitals and schools in Sana’a

<table>
<thead>
<tr>
<th>#</th>
<th>Location</th>
<th>Type of site</th>
<th>Freq(MHZ) at Pmax</th>
<th>Max P[µW/m²]</th>
<th>Max E[V/m]</th>
<th>ICNI RP (%)</th>
<th>Salz1 (%)</th>
<th>Salz2 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>In Front of Aljemhory hospital</td>
<td>GSM900</td>
<td>948.8</td>
<td>1517</td>
<td>0.756</td>
<td>1.78</td>
<td>151.7</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GSM1800</td>
<td>1819</td>
<td>101.65</td>
<td>0.196</td>
<td>0.33</td>
<td>10.165</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CDMA</td>
<td>877.8</td>
<td>3834</td>
<td>1.202</td>
<td>2.95</td>
<td>383.4</td>
<td>***</td>
</tr>
<tr>
<td>2</td>
<td>Typical police hospital(TPH)</td>
<td>GSM900</td>
<td>952</td>
<td>49.92</td>
<td>0.137</td>
<td>0.32</td>
<td>4.992</td>
<td>499.2</td>
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<tr>
<td></td>
<td></td>
<td>GSM1800</td>
<td>1818</td>
<td>97.60</td>
<td>0.192</td>
<td>0.32</td>
<td>9.76</td>
<td>976</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CDMA</td>
<td>877.6</td>
<td>81.01</td>
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<td>0.42</td>
<td>8.101</td>
<td>810.1</td>
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<tr>
<td>3</td>
<td>Blood Bank</td>
<td>GSM900</td>
<td>945.6</td>
<td>79.25</td>
<td>0.173</td>
<td>0.35</td>
<td>7.925</td>
<td>792.5</td>
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<tr>
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<td></td>
<td>GSM1800</td>
<td>1811</td>
<td>108.11</td>
<td>0.202</td>
<td>0.34</td>
<td>10.811</td>
<td>***</td>
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<td></td>
<td></td>
<td>CDMA</td>
<td>876.4</td>
<td>0.2726</td>
<td>0.011</td>
<td>0.027</td>
<td>0.0272</td>
<td>2.726</td>
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<tr>
<td>4</td>
<td>AL-Zobiry dispensary in Old Sana’a</td>
<td>GSM900</td>
<td>936</td>
<td>15.54</td>
<td>0.077</td>
<td>0.18</td>
<td>1.554</td>
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<td></td>
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<td>GSM1800</td>
<td>1810</td>
<td>0.336</td>
<td>0.011</td>
<td>0.01</td>
<td>0.0336</td>
<td>3.36</td>
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<td></td>
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<td>877.8</td>
<td>0.154</td>
<td>0.008</td>
<td>0.01</td>
<td>0.0154</td>
<td>1.54</td>
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<td>5</td>
<td>Zaid Bin Hartha school Shomila Area</td>
<td>GSM900</td>
<td>944.6</td>
<td>194.02</td>
<td>0.267</td>
<td>0.63</td>
<td>19.402</td>
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<td>1818</td>
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<td>1.854</td>
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<td>1.04</td>
<td>47.371</td>
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<tr>
<td>6</td>
<td>AL-delami school In AL-Mosbahi tunnel</td>
<td>GSM900</td>
<td>935.2</td>
<td>2428.6</td>
<td>0.957</td>
<td>2.28</td>
<td>242.86</td>
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<td>0.34</td>
<td>5.163</td>
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<td>Al-Moqbly school</td>
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<td>0.42</td>
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<td>877.8</td>
<td>1.52</td>
<td>0.024</td>
<td>0.06</td>
<td>0.152</td>
<td>15.2</td>
</tr>
<tr>
<td>9</td>
<td>Al-Nahta school In 45 tunnel</td>
<td>GSM900</td>
<td>938.4</td>
<td>139.37</td>
<td>0.229</td>
<td>0.54</td>
<td>13.937</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GSM1800</td>
<td>1818</td>
<td>2.92</td>
<td>0.032</td>
<td>0.05</td>
<td>0.292</td>
<td>29.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CDMA</td>
<td>876</td>
<td>267.95</td>
<td>0.318</td>
<td>0.78</td>
<td>26.795</td>
<td>***</td>
</tr>
<tr>
<td>10</td>
<td>AL-Ramah school In Al-Hasaba Area</td>
<td>GSM900</td>
<td>941.6</td>
<td>78.39</td>
<td>0.172</td>
<td>0.41</td>
<td>7.839</td>
<td>783.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GSM1800</td>
<td>1810</td>
<td>0.704</td>
<td>0.016</td>
<td>0.03</td>
<td>0.0704</td>
<td>7.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CDMA</td>
<td>878.2</td>
<td>60.96</td>
<td>0.152</td>
<td>0.37</td>
<td>6.096</td>
<td>609.6</td>
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</tbody>
</table>

The readings were collected and analyzed, then the highest readings were taken for every location for GSM900, GSM1800, and CDMA. In Fig. 5, the graph illustrated all the locations with its readings in µW/m² but the graph in Fig. 6 is illustrated all the locations with its readings in V/m. The highest readings were: For GSM900, maximum RF radiation level was in AL-delami school location in AL-Mosbahi tunnel. The power density in this location is 2428.6µW/m² (E=0.957V/m), it represents 0.052% of ICNIRP limit.
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Figure 5: Power density for measurements nearby some hospitals and schools in Sana’a.

Figure 6: Electric field for measurements nearby some hospitals and schools in Sana’a.

For GSM1800, maximum RF radiation level is in AL-delami school location also. The power density in this location is 706.50μW/m² (E = 0.516V/m). This value represents 0.008% of ICNIRP limit. For CDMA, the maximum level is in Aljemhory hospital area. The power density in this location is 3834μW/m² (E = 1.202V/m), it represents 0.09% of ICNIRP limit (4.38W/m²). Therefore, the reading in Aljemhory hospital location is the highest value, which is specifically at frequency 877.8MHz.

4.2 Spot measurement at difference distances

The second part for these type of measurements was at different distances from base stations. These measurements were conducted for several sites, as exemplified in Table 4. Two sites in New Sana’a University and Asser Area were chosen. The variation of power density with horizontal distance from base station at Sana’a University was illustrated in Fig. 7 and Fig. 8 where show the variation of electric field
with distance. In Sana’a University, measurements were carried out at several points with different distances from the base station, that is, at 30m, 50m, 100m, 130m, 150m, and 200m as demonstrated in Table 4. This table shows the measurements at these distances and power density values at all bands. These data were collected and analyzed for every value with its distance, then drawn in graphs that illustrate the highest readings at distances (100m-150m) from base station as shown in Figs. 7 and Fig.8. For GSM900 the highest value for power density at a distance of 130m is 1620 µW/m² (0.78v/m), it represents 1.89 % of ICNIRP limit.

Table 4: Measurements at different distances from base station in New Sana’a University

<table>
<thead>
<tr>
<th>#</th>
<th>Distance (m)</th>
<th>Power density ( dBm &amp; µw/m²&amp; v/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>GSM900</td>
</tr>
<tr>
<td>1</td>
<td>30</td>
<td>-35</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>-31</td>
</tr>
<tr>
<td>3</td>
<td>100</td>
<td>-24</td>
</tr>
<tr>
<td>4</td>
<td>130</td>
<td>-19</td>
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<td>-22</td>
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<tr>
<td>6</td>
<td>200</td>
<td>-27</td>
</tr>
</tbody>
</table>

Figure 7: Variation of power density with horizontal distance from base station at Sana’a University.

For GSM1800 the highest reading for power density at a distance of 150m is 213.4 µW/m² (0.28 V/m), it represents 0.68 % of ICNIRP limit. For CDMA the highest value for power density at a distance of 150m is 1431.6 µW/m² (0.73 v/m) it represents 1.77 % of ICNIRP reference level.
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Figure 8: Variation of Electric field with horizontal distance from base station at Sana'a University.

In Asser Area, the measurements were performed at distances less than 100m: at 10m, 20m, 30m, 50m, and 100m from base stations. The values were illustrated in Fig. 9 and Fig. 10 that showed power density with µW/m² and Electric field with v/m at every distance for all bands GSM900, GSM1800, and CDMA. The diagrams illustrate the highest readings registered at very near distances from a mobile phone base station that is less than 30m as shown in Figs. 9 and 10, in other words, close to base stations in the surface of building. These measurements exceeded the Salzburg standard for exposure limit from RF radiation for mobile network, and it is close to Switzerland and Italy limit.

Figure 9: Variation of the power density with horizontal distance from base station at Asser Area.

The highest value for power density for GSM900 was 29045 µW/m² or 2.905 µW/cm² (3.31v/m) at 10m distance. The percentage of this value to Salzburg limit is 2904.5% an increase of 29 times. The percentage
of this value to Italy limit is 29.05% with 3.44 times less. The percentage of this value to ICNIRP limit is 8% with the decrease of 13 times. As a result, the levels of RF radiation on rooftop of buildings around the base station are more than the levels in ground and maybe it imposes danger.

![Electric field variation](image)

**Figure 10:** Variation of electric field with horizontal distance from base station at Asser Area.

For GSM1800 the value of power density at 10m is 11642 µW/m² or 1.164 µW/cm² (2.1v/m), this value also had exceeded Salzburg limit and close to Switzerland and Italy limits. The percentage of this value to Salzburg limit is 1164.2% with an increase of 11.62 times. The percentage to Italy limit is 11.6% that is 8.6 times less. The percentage to ICNIRP limit is 3.6% with decrease by 27.8 times. Also for CDMA the value of power density at 10m is 23430 µW/m² or 2.343µW/cm² (2.97v/m). This value also exceeded Salzburg limit and close to Switzerland and Italy limits. The percentage for this value from Salzburg limit is 2343% with increasing 23.43 times. The percentage from Italy limit is 23.43% with 4.3 times less. The percentage from ICNIRP limit is 7.3% with 13.7 times less. From these measurements data it is concluded that the strongest values for all bands measured are at near distances from mobile phone base stations. Hence, it is advised not to approach the base stations especially for long term exposure on rooftop of buildings.

### 4.2 Future work

Our future work is to expand our research in the field of electromagnetic field strength measurements for whole the country. We will do some measurements in some rural areas too. We will focus on electromagnetic field strength emitted from radiobroadcasting in Eden located in Alhasswah and Sana’a radiobroadcasting centers. Because, we have some uninterested data about both radio stations. We are currently try to collaborate with other universities and RFR research centers. Increase the RFR culture for Yemeni people at: Schools, and Universities. Indeed, we started to focus on invisible pollution in Yemen, using local and national radiobroadcasting centers, journals, TV, and to organize some seminars.

### 5. Analysis and conclusions

This study is considered not only scientific work but humanitarian one where, we focused on measurements of RFR nearby schools, hospitals, universities and high traffic public areas as city center for example. This study found that the power densities were compliant or lower than ICNIRP reference level and FCC limit for general public, and close to some national standards like Italian, Bahraini, Kuwaiti standards and it had exceeded Salzburg limit for general public exposure. However, the data from this
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study only may still not enough to conclude firmly that people may not have adverse health effects from EMR transmission from mobile phone systems. This research is a field study. The measurements of RFR levels were implemented in different areas of Sana’a. The authors give a good idea theoretically and practically about RFR periodically at Telecom final year students at Faculty of Engineering, Sana’a University to be have a scientific knowledge about invisible pollution. One of the most important recommendation of this work that the Ministry of Telecommunication, and Faculties of Engineering at governments universities in Yemen to have measurement equipment’s and should train the students about RFR. The second important recommendation of this study is that the Yemeni people should have simple information about this invisible pollution by public media and we started to do that. The third recommendation of this study is to give an idea for students at schools about RFR from mobile BTS, and radio broadcasting located in the cities. In conclusion, from these measurements data it is concluded that the strongest values for the all bands measured are at near distances from mobile phone base stations. Hence, it is advised not to approach from base stations especially for long term exposure on rooftop of buildings.

6. References

1. Roger Field. 2010. Yemen’s telecom limbo, Yemen Mobile Operator Forecast, Yemen to have 20 million mobile subscriber connections in 2015, Published on Monday, 13 September.


