ELECTRIC-FIELD STRENGTHS MEASURED NEAR PERSONAL TRANSCEIVERS

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Abstract
Electric-field strengths were measured at a number of points near 5-W personal transceivers. The points were located on cylinders of revolution with radii of 7 and 12 cm around the antenna. The transceivers operated on four authorized frequencies of 40.27, 162.475, 464, and 823 MHz, and radiated powers of 5, 5, 5, and 3 W, respectively. In some cases, these measured values exceeded the exposure limits suggested in ANSI Standard C95.1-1982.

Key Words: Electric fields, measurement of near fields, personal transceivers.

Introduction
Law enforcement and other public safety personnel use various types of communication equipment in the performance of their day-to-day activities. A decade ago, most of these radios generated between 1 and 2 W of output power. In the past few years, however, transceivers that produce as much as 5 or 6 W of output power have become available and are used as a means of improving communication range and system reliability. Unfortunately, a by-product of this enhanced capability is an increase of field strengths in the vicinity of the transceiver and its antenna. In addition, there is increasing use of cellular phones at frequencies of 800-900 MHz at either 0.5 or 3.0 W of power.

We measured electric-field strengths (E) at locations described by cylinders of increasing radii with the antenna of the transceiver at the center of the cylinder.

A more complete description of this work is given by Adams, Wu, and Budlong [1].

Instrumentation
The electric-field strength was measured with a computer-controlled array of 10 isotropic probes [2]. Each probe has 3 orthogonal dipole elements capable of measuring x, y, and z components of E. The magnitude of E (square root of sum of squares) is calculated, appropriate calibration factors are added by the computer, and absolute values of E are reported.

A support structure held the probes in a vertical array with a separation of 10 cm between each probe. The support structure was built of nonmetallic material so as to minimize reflections. Probe 1 was at the bottom of the array while probe 10 was at the top. The support structure is shown in figure 1. The personal transceiver was supported above the rotator by a long fiberglass tube. The top of the tube had a wooden platform to support the personal transceiver while the bottom was attached to the rotator. The wooden table was covered with anechoic material to reduce reflections. The probe structure was also supported by a wooden table. The probe array could be repositioned horizontally to change separation distance. It could also be repositioned vertically. The vertical reference point was determined by placing the base of the antenna on the transceiver at the same height as probe 5. All the personal transceivers had different antenna lengths and case dimensions.

Figure 1. Support structure used in anechoic chamber.

Horizontal separation distances of 7, 9.5, 12, 14.5, 17, 27, 37, 67, 97 cm were used, but only 7 and 12 cm separations are reported here. Smaller increments at smaller separations were necessary to show the more rapid spatial variations in field strengths close to the transceiver. However, at 7 and 9.5 cm, the side of the transceiver case would hit the array of probes between approximately 135° and 225° of rotation, so no values could be recorded within those limits.

The measurements were made with the probe array held stationary at one of several separation distances while the personal transceiver was rotated in uniform increments. Rotation was clockwise as seen from above, with the 0° point on the short side of the transceiver case toward the probe array. The size of the rotation increment was a compromise between stepping speed and battery discharge rate.

In order to key the transceiver on, a pneumatic switch was improvised. It consisted of a rubber bulb which was taped and strapped to the push-to-talk switch. This switch was linked with a plastic tube to a hand-operated air pump. As the pump was actuated, the air bubble attached to the personal transceiver expanded and turned on the transmitter. The personal transceivers were never left on for more than 45 s, since there was a noticeable decrease in the electric field as the battery discharged and the output stage heated. After each rotation of 360° the transceiver batteries were recharged so that during each rotation the battery charge was consistent and adequate.

Test Facilities
We made measurements using either of two facilities depending on the frequency of the transceiver. For transceivers operating at 464 and 823 MHz, we made measurements in an anechoic chamber. The measurements were fully automated, since the chamber is equipped with a five-axis positioner that allowed rotation of the personal transceiver 360° in 3.6° or 7.2° steps. This allowed for 100 or 50 data points, respectively.

For transceivers operating at 40.27 or 162.475 MHz, we made measurements on an outdoor ground screen since the absorber in the anechoic room is not effective at these lower frequencies. The measurements generally showed little variation on the screen.

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For transceivers operating at 40.27 or 162.475 MHz, we made measurements on an outdoor ground screen since the absorber in the anechoic room is not effective at these lower frequencies. The measurements
on the ground screen were not automated and therefore took more time; only 16 steps of rotation could be used before the battery charge was reduced below an acceptable level. All the rotations were done by hand in 22.5° steps. The rotation was accomplished by rotating a fiberglass support tube from a tunnel under the ground screen. An additional tube was attached to the support tube to allow this rotation and to indicate the azimuth.

Because the probes were sensitive to sunlight, the probe fixture had to be wrapped in black plastic. The probes were not affected by moderate changes in temperature. At the lower frequencies fewer increments of separation distance were used, and offsets in elevation were also omitted since the spatial variations in field strength are not as rapid at the longer wavelengths.

The probes were calibrated and have an uncertainty of ±1 dB in field strength. All values reported have this as a basic uncertainty. The values measured on the ground screen, where the positioning uncertainty was ±1 cm, have the same basic uncertainty, but the values may not have been measured at exactly the position reported. At 40 MHz, this causes an additional ±4 dB uncertainty; at 162 MHz, an additional ±3 dB uncertainty. Positioning errors in the anechoic chamber were very small, less than ±1 mm; this causes an additional ±0.25 dB uncertainty.

If the transceiver is held in an operator's hand there may be an increase of field strengths over those measured when the transceiver is supported by a plastic structure. This is due to the increase in effective size of ground screen for the monopole antenna of the transceiver. This effect was about +3 to +4 dB in limited cases, but was not thoroughly investigated.

**Measured Data**

For each of the transceivers measured in the anechoic chamber, 25,500 data points were recorded, and from these, 8500 data points for the magnitude of E were calculated. Only 336 data points were recorded for a transceiver measured on the ground plane.

Only a sample of the measured data can be shown; several formats are given to illustrate methods of displaying the fields around the units. Figures 2-4 are such illustrations. Figure 2 shows the individual x, y, and z components of electric field strength as well as the magnitude for 360° rotation at a 12 cm spacing and 823 MHz. Figure 2a is for probe 4, 2b is for probe 6, and 2c is for probe 8. Figure 3 shows field magnitudes for 9 probes for 7-cm spacing (closest distance measured) at 162 MHz. The discontinuity in electric field as a function of rotation was caused by the transceiver case striking the probe array at this close spacing. The highest levels were recorded on the number 5 probe. Figure 4 is a 3-dimensional plot in cylindrical coordinates; it shows the spatial variations in field strength around the antenna of an 823 MHz transceiver. The radii of the disks are proportional to measured field strengths; the highest field strengths occur in the volume immediately adjacent to the transceiver antenna. There are no nulls or low field strengths in the immediate vicinity of the transceiver antenna.
Figure 3. Plot of electric field around transceiver D162 (162 MHz) at a separation of 7 cm. Fields detected by 9 probes are shown as a function of angle of rotation. The gap between 120° and 240° is because at this spacing the case of the transceiver hit the probe array structure and no data could be recorded.

Figure 4. Three-dimensional plot of magnitude of electric field around transceiver B823 (823 MHz). Radii of disks are proportional to the magnitude of electric field. Separation between transceiver antenna and probes is 12 cm. The maximum value of field is marked with the black dot, and is 95 V/m at an angle of rotation of 72°.

Comparison of Measured Data with ANSI Standard

It is not within the scope of this study or within the mission of the National Institute of Standards and Technology (NIST) to state what levels of electromagnetic fields constitute a health hazard. NIST is responsible for the accurate measurement of electromagnetic fields.

The only guidance available is in the ANSI C95.1-1982 Standard, Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 300 kHz to 100 GHz [3]. This ANSI standard gives limits in units of field strength squared (V/m)² for electric field strength, (A/m)² for magnetic field strength, and mW/cm² for power density as a function of frequency. These limits were selected to keep the specific absorption rate (SAR) below 0.40 W/kg of human tissue as averaged over the whole body and the SAR below 8 W/kg averaged over any 1 g of tissue.

Figure 5 is a graph of maximum measured field strengths plotted relative to the field strength limit for human exposure to radio-frequency fields as given in the ANSI C95.1-1982 Standard. These measured data show that the field strengths are clearly greater than the recommended levels at 40 and 162 MHz, where E is about 1 order of magnitude greater than the limit, which means that E² (or power density) is about two orders of magnitude greater than the value specified in this standard.

A later revision of this standard was published in 1991 [4] subsequent to this work. Limits are more complicated to calculate and interpret in this standard, in that fields are averaged over a whole-body cross section. Nevertheless, my work reports measured values of field strength only, with no assessment of biological or other effects.

Conclusions

The measured values of field strength from these transceivers are higher than the exposure limits of the 1982 ANSI standard, quite significantly higher at 40 and 162 MHz. What effects this causes to humans is not known.

Acknowledgments

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References


