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EXPERIMENTAL AND ANALYTICAL STUDY ON INTERACTION BETWEEN NEAR-ZONE EM FIELD OF CB-RADIO ANTENNA AND HUMAN BODY

[redacted]

Near-field coupling between a CB-radio antenna and the human body of its operator in near proximity is investigated experimentally and analytically. The potential biological hazard associated with CB-radio EM radiation at 27 MHz has recently become a public concern due to the vast number of CB-radio operators and evidence that some CB antennas are operated with high input power. Although the EM field excited in a biological body by impressed plane-wave illumination has been successfully quantified, the interaction between the nonuniform near-zone field of a radiating element and such a body is not well understood. The electric field excited in a human-body model due to its coupling with a CB antenna as well as the antenna current and impedance are studied.

A simultaneous pair of coupled, tensor integral equations is developed for the unknown current excited in a CB antenna and the electric field induced in a human-body model located close to the antenna in its near-zone field. These equations are solved numerically by the method of moments for various antenna-body configurations. Accuracy of the analytical solution for a monopole antenna coupled with a rectangular-cylindrical body model is confirmed by good agreement between the induced body fields and antenna impedances predicted analytically and measured experimentally with phantom material and saline body models.

Coupling between antenna and body is found to be strongly dependent upon antenna-body proximity and environmental effects such as conducting ground. 3.5% of the input power to a quarter-wavelength monopole is coupled into a human-body model over conducting ground at 20 cm separation. In this case, antenna input power of 235 watts excites the same maximal induced field in the human body as a 10 mW/cm^2 impressed plane wave. Very tight coupling is demonstrated to occur when the CB radio and its antenna are in direct, capacitively-coupled contact with the outstretched arm of a simplified human-body model. Under these circumstances, 77% of the antenna input power is coupled into the body and relatively intense fields and SAR's are excited, particularly near the contact point between CB radio and body extremity. Extensive experimentally-measured and analytically-predicted induced fields, antenna currents, and impedances confirm the capability of the numerical solution for predicting antenna-body coupling with adequate accuracy.

Near-field coupling between a CB-radio antenna and the human body of its operator located in near proximity is investigated experimentally and analytically. The potential biological hazard associated with CB-radio EM radiation at 27 MHz has recently become a public concern due to the vast number of CB-radio operators and evidence that some CB antennas are operated with high input power. Although the EM field excited in a biological body by impressed plane-wave illumination has been successfully quantified, the interaction between the nonuniform near-zone field of a radiating element and such a body is not well understood. Fields and SAR's induced in a human-body model located in near proximity to a CB antenna as well as the antenna current and impedance are measured experimentally and compared with those quantified theoretically by numerical solution of a coupled system of tensor integral equations.

A CB antenna is located in near proximity to a heterogeneous, conducting, polarizable human-body model V_b with electrical parameters $(\varepsilon, \mu, \sigma)$ as indicated in Fig. 1. Current $\vec{I} = \hat{s}I(s)$ is excited in the antenna by potential V_o and is coupled with induced current $\vec{J}_{eq} = \tau\vec{E}$ in V_b. s is a displacement variable along the antenna and $\hat{s}$ is a unit vector tangent to its surface; $\vec{E}$ is the field in V_b with equivalent complex conductivity $\tau = \sigma + j\omega(\varepsilon - \varepsilon_o)$. A pair of simultaneous integral equations for the coupled unknowns $\vec{I}$ and $\vec{E}$ is obtained as

$$\left[1 + \frac{\tau(\vec{r})}{j3\omega\varepsilon_o}\right]\vec{E}(\vec{r}) - \text{P.V.} \int_{V_b} \tau(\vec{r}\,')\vec{E}(\vec{r}\,') \cdot \overleftrightarrow{G}(\vec{r},\vec{r}\,')dv' - \int_{ant} I(s')\hat{s}' \cdot \overleftrightarrow{G}(\vec{r},s')ds' = 0 \ldots \text{for all } \vec{r}\varepsilon V_b$$

$$\int_{ant} I(s')K(s,s')ds' + \frac{j4\pi}{\zeta_o}\int_o^s du \sin k_o(s-u)\left[\hat{u}\cdot\int_{V_b}\tau(\vec{r}\,')\vec{E}(\vec{r}\,')\cdot \overleftrightarrow{G}(u,\vec{r}\,')dv'\right] = A\cos k_o s + B\sin k_o s - \frac{j2\pi}{\zeta_o}V_o \sin k_o|s| \ldots \text{for all } s \text{ on ant},$$

where P.V. denotes the principal value in the sense defined by Van Bladel, $\overleftrightarrow{G}$ is the free-space tensor Green's function, $\hat{u}$ is a unit tangent vector to the antenna at u, (k_o, ζ_o) are the free-space wavenumber and impedance, $K(s,s') = \exp(-jk_oR)/R$ with $R = \sqrt{(s-s')^2 + a^2}$, and (A,B) are integration constants determined by $I(s) = 0$ at antenna extremeties. These equations are solved numerically by the method of moments.

The induced fields and SAR's excited in a simplified human-body model by a half-wave dipole antenna with 1 watt input power are indicated in Fig. 1 together with antenna current, impedance, and relevant dimensions. Validity of the numerical solution for this body model was confirmed by quantifying the field induced by 10 mW/cm^2 plane-wave illumination; absorbed power was calcualted as 11.14W, which agrees well with the 12W predicted by Massoudi, et al. The dipole near field is weakly coupled with the body model since only 0.272% of the antenna input power is dissipated in the body. Coupling is strongly dependent upon proximity and environmental effects; for example, 3.5% of the input power to a quarter-wave monopole is coupled into the same body model in contact with conducting ground. With 3.5% coupling, an antenna input power of 235 watts is found to induce a maximal field equal to that excited by 10 mW/cm^2 plane-wave illumination. These results are greatly modified by antenna-body proximity variations and other environmental effects.

Experimentally measured induced fields and antenna impedances are compared with those predicted analytically in Figs. 2 and 3 for a frequency scaled (600 MHz) antenna-body system. Fig. 2 indicates excellent agreement between measured and predicted relative induced-field distributions in a phantom-material body model coupled to a $\lambda_0/4$ monopole above conducting ground. Measured and predicted input impedances to a $\lambda_0/8$ monopole coupled to a NaCl saline body model over conducting ground are compared in Fig. 3 as a function of antenna-body spacing. These results confirm the accuracy of numerical solutions to the coupled system of integral equations for antenna currents and induced fields in the human-body model.

A study concerning a simplified human-body model making direct, capacitively-coupled contact to a hand-held CB radio with its short-monopole antenna is presented in Fig. 4. Induced fields and SAR's in the body, as quantified by numerical solution to the above integral equations, are indicated as well as the current and impedance to the antenna driven by an input power of 1 watt. Very large fields and SAR's are excited in the body, particularly near the contact point between arm and CB radio. Coupling between antenna and body is observed to be greatly increased by the direct contact, with 76.6% of the antenna input power dissipated in the body.

Extensive numerical results, both measured and calculated, for induced fields and antenna near fields, currents, and impedances associated with coupled antenna-body systems of various configurations will be presented at the symposium.

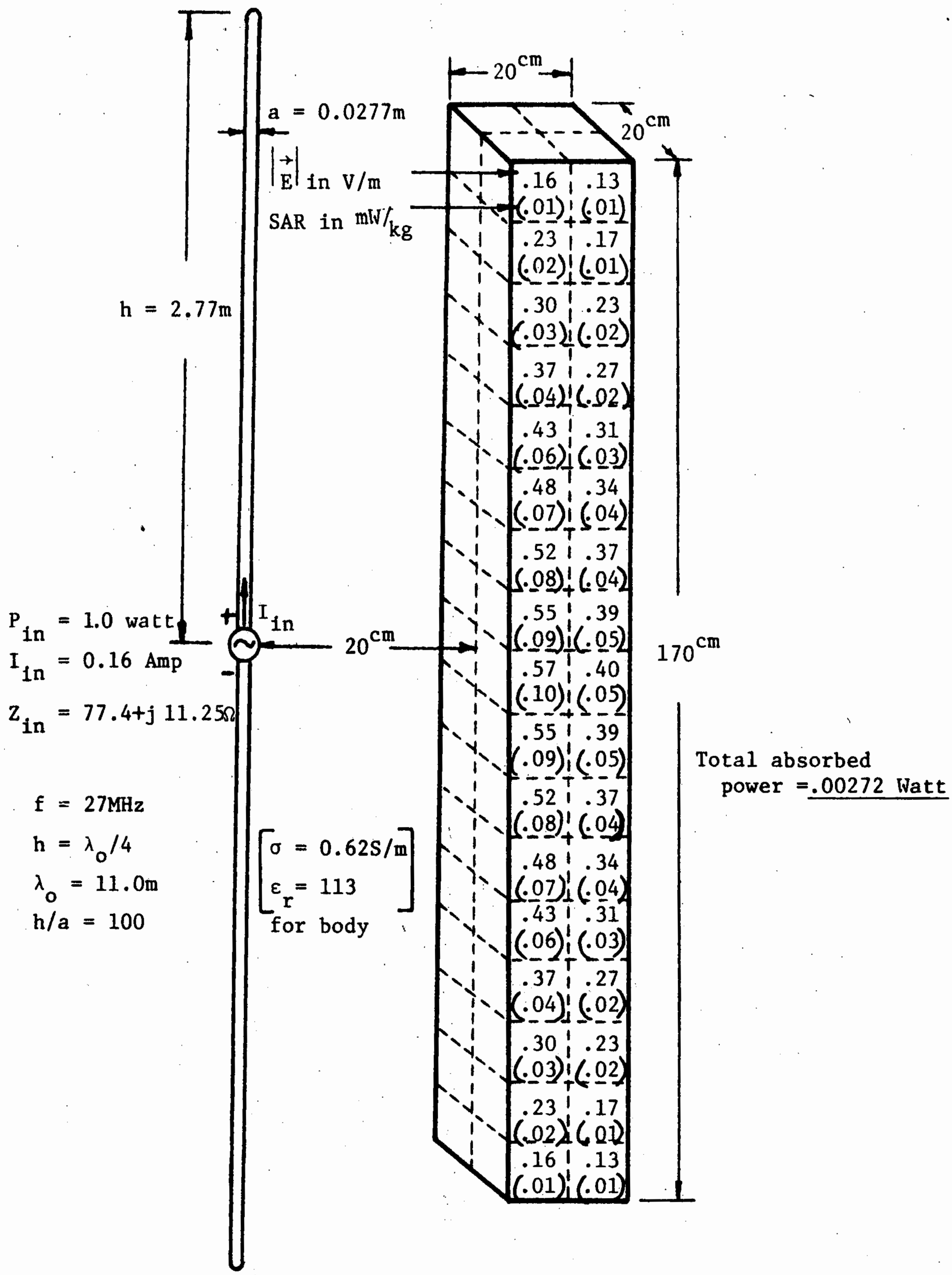


Fig. 1. Distributions of the induced electric fields $|\vec{E}|$ and SARs inside a cylindrical model of man which is located in the immediate vicinity of a CB dipole antenna in free-space.

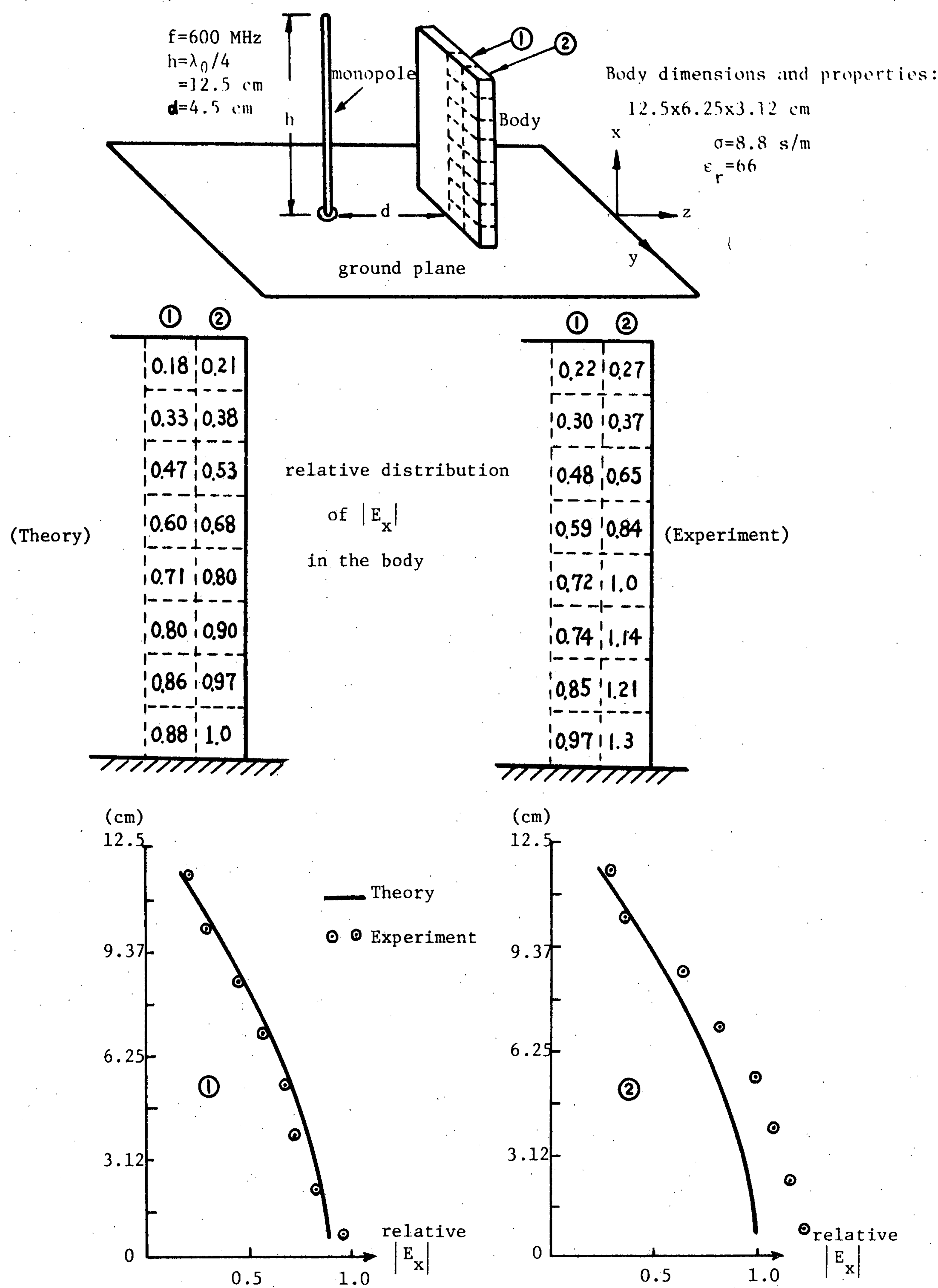
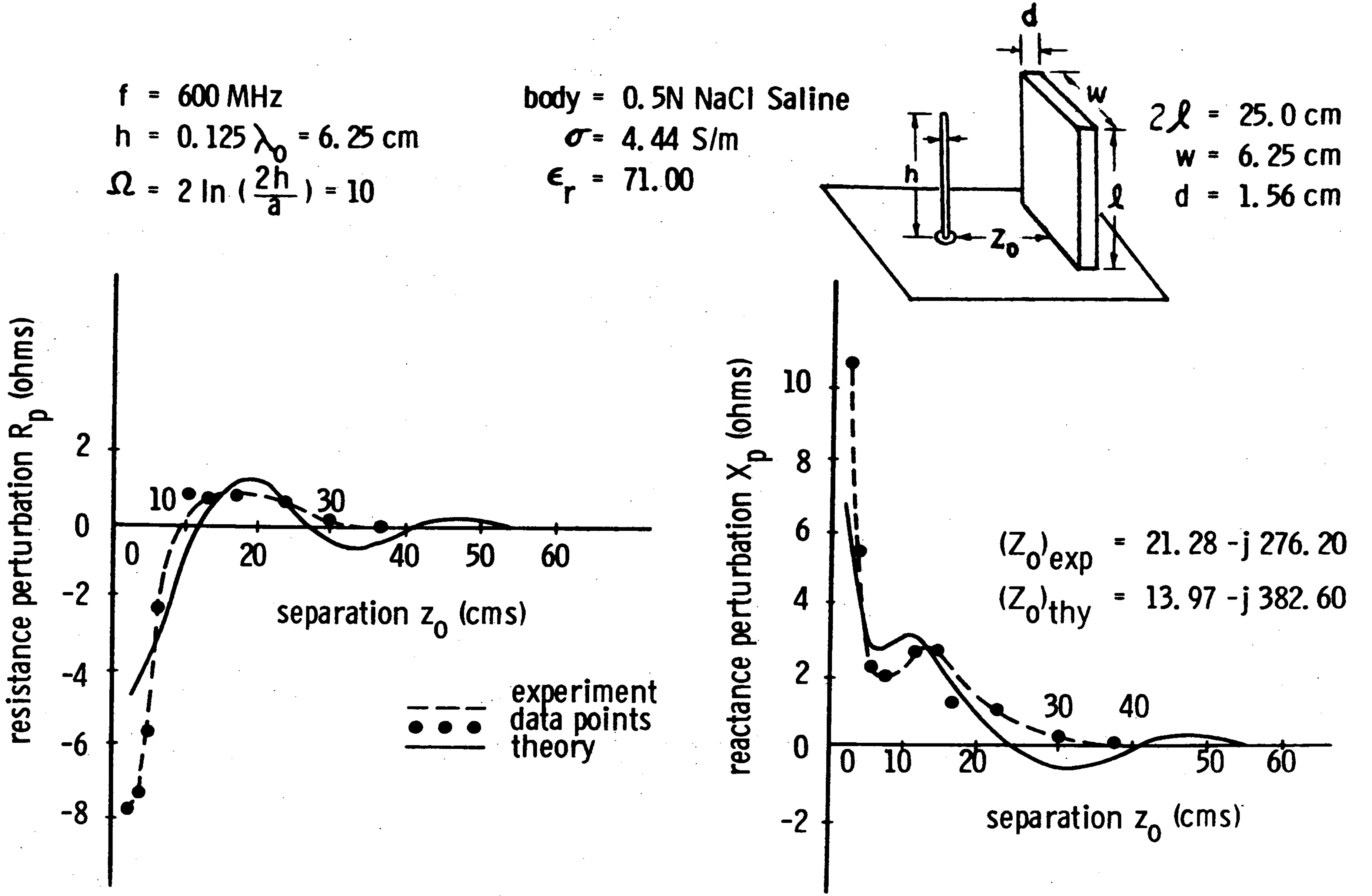


Fig. 2. Theoretical and experimental results on the x-components of the induced electrical fields in a conducting body of 12.5x6.25x3.12 cm placed at a distance of 4.5 cm from a $\lambda_0/4$ monopole.



a. perturbation R_p to antenna resistance.

b. perturbation X_p to antenna reactance.

Figure 3 Dependence of antenna impedance $Z_{in} = Z_0 + Z_p$ (Z_0 = free-space impedance, Z_p = perturbation due to body proximity effect) upon antenna-body spacing z_0.

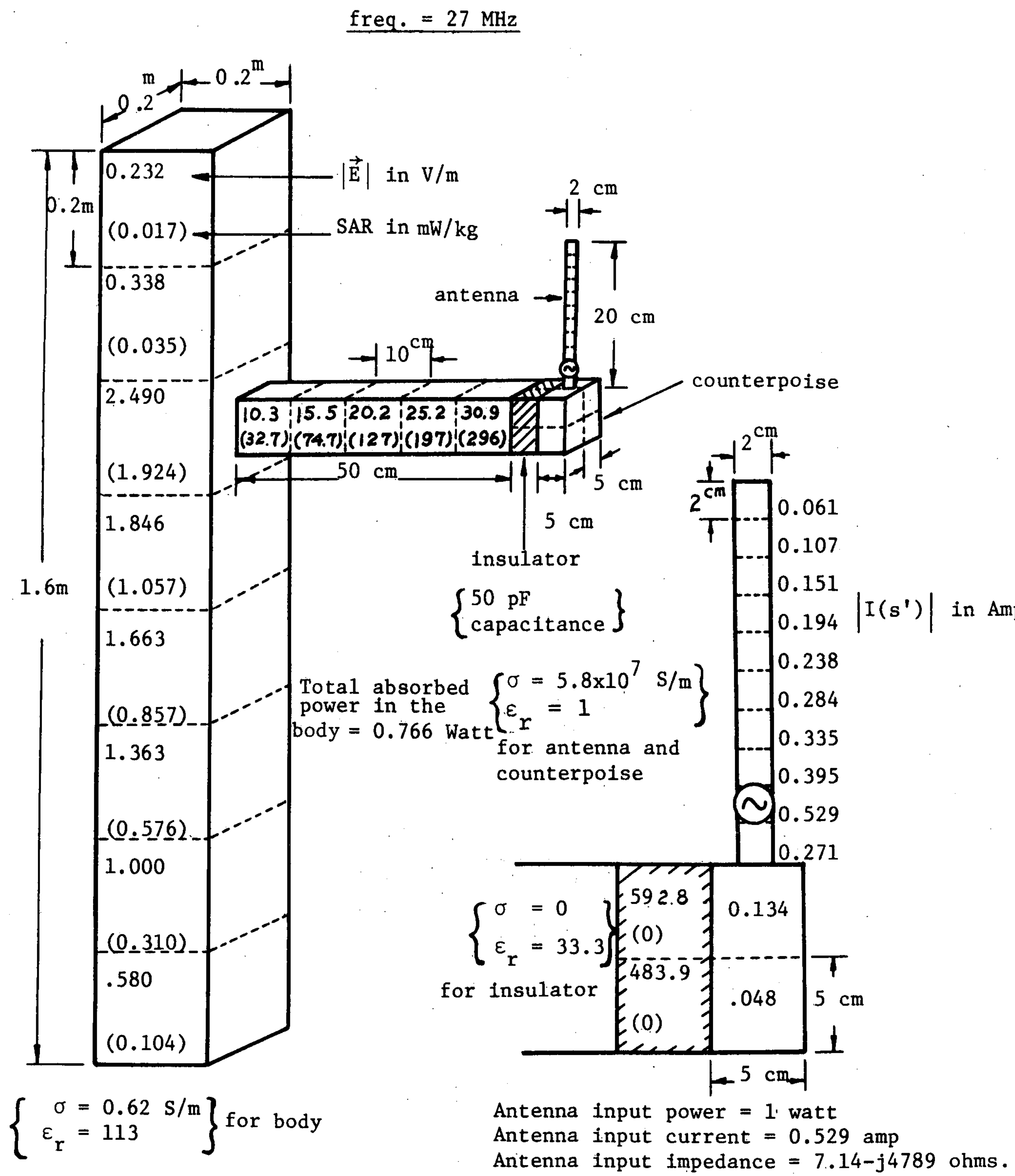


Figure 4. Distributions of the induced electric fields $|\vec{E}|$ and SARs in the body and the antenna current on a hand-carried CB radio antenna when the antenna input power is 1 watt.