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Automatic RF Input Power Level Control Methodology for SAR Measurement Validation

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Abstract

Evaluation of radiating radiofrequency fields from hand-held and body-mounted wireless communication devices to human bodies are conducted by measuring the specific absorption rate (SAR). The uncertainty of system validation and probe calibration in SAR measurement depend on the variation of RF power used for the validation and calibration. RF input power for system validation or probe calibration is controlled manually during the test process of the existing systems in the laboratories. Consequently, a long time is required to reach the stable power needed for testing that will cause less uncertainty. The standard uncertainty due to this power drift is typically 2.89%, which can be obtained by applying IEC 62209 in a normal operating condition. The principle of the Automatic Input Power Level Control System (AIPLC), which controls the equipment by a program that maintains a stable input power level, is suggested in this paper. The power drift is reduced to less than ±1.16 dB by AIPLC, which reduces the standard uncertainty of power drift to 0.67%.

Key Words: Calibration, Power Level Control, Specific Absorption Rate, Uncertainty, Validation.

I. Introduction

The exposure of humans to radiofrequency fields from hand-held and body-mounted wireless communication devices is assessed by measuring the specific absorption rate (SAR). The SAR is the initial time derivative of temperature in the human tissue of the head or body in kelvins per second as Eq. (1) [1].

$$\mathrm{SAR} = c_h \frac{\Delta T}{\Delta t} \tag{1}$$

The term c_h is the specific heat capacity of the simulated tissue, ΔT is the temperature increase due to the RF exposure, and Δt is the elapsed time duration for the temperature increase measurement in (1). From (1), it is possible to quantify the SAR value by the field in the tissue.

$$\mathrm{SAR} = \frac{\sigma|E|^2}{\rho} \tag{2}$$

where σ is the conductivity of the tissue and ρ is the density of the tissue [1, 2].

The SAR System validation test should be conducted before starting a SAR measurement procedure for verifying that the system operates within its specifications. The test setup for validation consists of a flat phantom and a system validation source. In the SAR system validation, the measured 1 g and/or 10 g averaged SAR value produces the numerical reference peak special-average SAR values in IEC 62209 [2, 3]. The uncertainty of the power delivered to the validation source is kept as low as possible. This requires the use of a test setup with directional couplers and power meters during the system check, as shown in Fig. 1 [2, 3].

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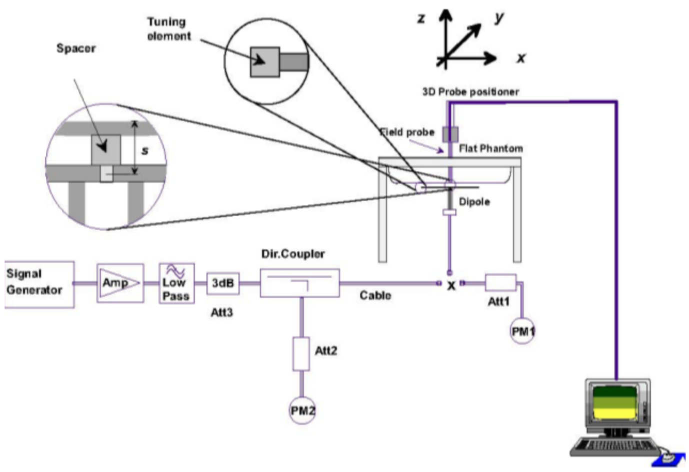

Fig. 1. Test setup for the system check and validation.

The power source setup is also used for the probe calibration. The expanded uncertainty of the SAR measurement system is approximately 30%. The power drift in the validation test or in the waveguide for probe calibration is around 5%, which makes up a substantial part of the total uncertainty parameters. Fig. 2 shows the power drift without Automatic Input Power Level Control (AIPLC), which is the common phenomenon in the normal operation conditions with the usual signal generator and power amplifier.

The RF input power for system validation in Fig. 1 is controlled manually during the test process; thus, it requires more than 1 hour to reach the stable state to be used for a validation test. The IEC 62206 Part 1 and Part 2 require a power drift less than 5% in normal operating condition and the standard uncertainty by this power drift is 2.89%. The standard uncertainty (u_i) of power drift is calculated from the upper limit (a_+) and lower limit (a_-) of the power drift, depending on the rectangular probability distribution function defining $a = (a_+ - a_-)/2$, then $u_i = a/\sqrt{3}$ [4].

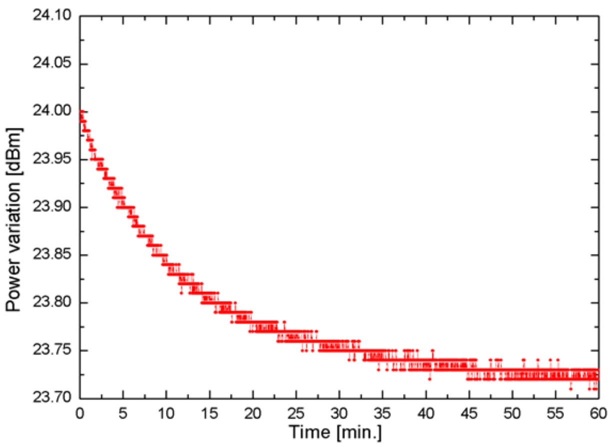

Fig. 2. The input power variation patterns to the operation time without the application of Automatic Input Power Level Control (AIPLC).

II. Signal Source for the Validation System and AIPLC Algorithm

The wiring schematic diagram of the signal source for SAR validation system is shown in Fig. 3. A computer controls both the signal generator and the power meter automatically through a GPIB cable and its board. It also controls the amplifier through the RS232C cable.

The equipment is controlled by the programmed input power level control system for the stable input power level,

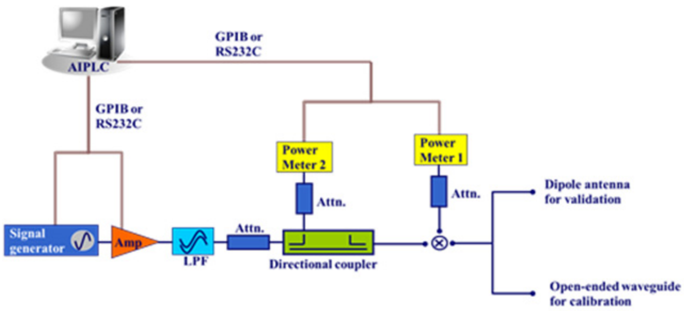

Fig. 3. Schematic diagram of signal source for specific absorption rate validation with Automatic Input Power Level Control (AIPLC).

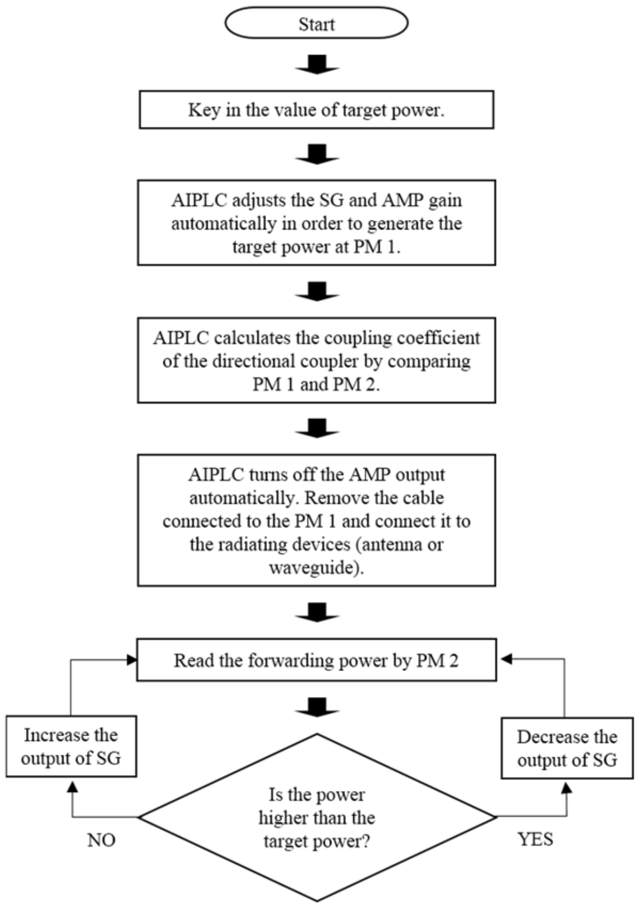

Fig. 4. The algorithm of the Automatic Input Power Level Control (AIPLC) work process. SG=signal generator, AMP=amplifier, PM=power meter.

whose algorithm is described in Fig. 4.

The AIPLC algorithm starts with clicking of the start button in Fig. 4, after setting up the equipment as shown in Fig. 3, and follows the procedure described hereafter.

- Key in the value of input power to power meter 1, e.g., 24 dBm.
- In the case where the value of power meter 1 approaches the output power required, then read the value of power meter 2 to check the correlation between the values of power meters 1 and 2. The value of power meter 2 is used as a reference to maintain a stable output power.
- The signal generator and amplifier are controlled automatically to maintain the supply of reference value of power meter 2 to the target device (a dipole antenna for the validation test, or an open-ended waveguide for probe calibration) [5].

III. RF Output Power Measurements with AIPLC

Figs. 5 and 6 show the output RF power variations with respect to operation time when the AIPLC is applied to the amplifier or to the signal generator. The power variation obtained by controlling the gain of the amplifier with AIPLC was about ±0.125 dB, and the power variation obtained by controlling the output of signal generator was less than ±0.05 dB.

AIPLC can be applied when calibrating the probe conversion factors. The conversion factor in tissue-equivalent liquid is determined by generating locally known field values inside the tissue with analytical fields in waveguides. The use of this method for calibrating probes in lossy liquids must take into account the net RF power dissipated in the waveguide by accurate measurements.

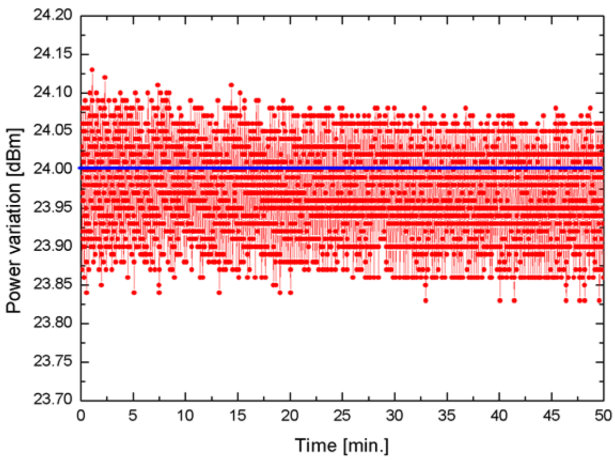

Fig. 5. Output power variation characteristics by controlling the amplifier gain.

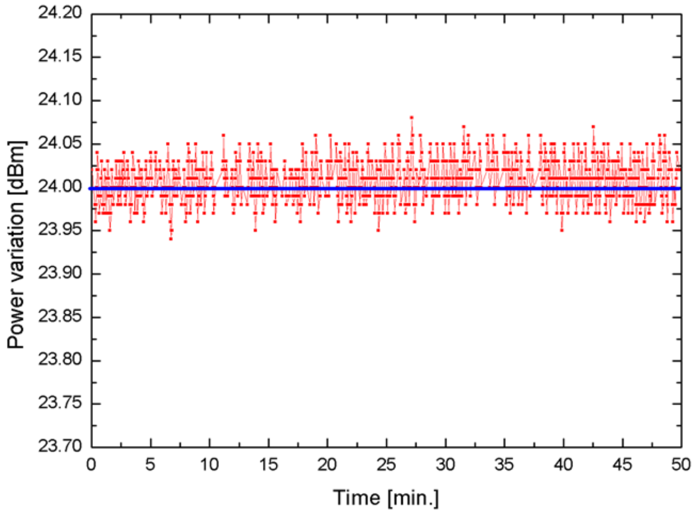

Fig. 6. Output power variation characteristics by controlling the signal generator output.

Table 1. The probe CFs with and without the application of AIPLC

Probe CF	Test sequence					
	1	2	3	4	5	SD
With AIPLC	5.01	5.01	4.96	5.00	5.00	0.04
Without AIPLC	4.82	4.84	4.92	4.96	4.81	0.13

AIPLC = Automatic Input Power Level Control, CF = conversion factor, SD = standard deviation.

This requirement implies precise measurement of the incident power, reflected power, and reflection coefficient at the waveguide input port [6].

$$|E|^2 = \sum_{i=1}^{3}|E_i|^2 = \sum_{i=1}^{3}\frac{f_i(V_i)}{\eta_i\psi_i} \quad (3)$$

Here, E_i (i=1, 2, 3) are the components resulting from the projection of the E-field vector on the orthogonal sensors, $f_i(V_i)$ is a linearizing function of the rectified sensor signal V_i, η_i is the sensitivity of sensor dipole in air for the sensor aligned with the field vector, and ψ_i is the conversion factor, which is the ratio of the sensor response in air to the response in the dielectric media [6].

The variation range of the conversion factors obtained without AIPLC application was from −1.17% to 1.79% and the standard deviation was 0.13.

On the other hand, the variation range of the conversion factors with AIPLC was reduced from ±0.7% to ±0.28%, and the standard deviation was 0.04. The conversion factors with and without the application of AIPLC are given in Table 1.

IV. Conclusions

The required power drift of RF input power in validation and calibration process should be less than 5% according to IEC 62209-1. Currently, the input power for system validation or probe calibration is controlled manually during the process, so a long time is required to reach to the stable power needed for use in testing that will induce the least uncertainty. The AIPLC concept was suggested and implemented in the SAR measurement system. The application of AIPLC for validation of the SAR measurement system and for probe calibration process helps to maintain a stable RF output power from the start of the test by controlling the signal generator output or amplifier gain, which reduces the uncertainty due to RF power drift from 2.89% to 0.67%.

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