Analysis of SAR Probe Performance in Presence of Wideband Signals

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Abstract

The introduction of new digital signals with spread spectrum modulation has generated the necessity to evaluate the behavior of the available traditional instruments, which are historically used to assess the field for human body exposure. For this reason, SAR probes have been tested, in order to evaluate the uncertainties introduced on their output in presence of a set of wideband signals. A proper experimental set-up has been designed and pre-characterized.

1.Introduction

In the recent years wireless systems have exploited spread spectrum waveforms in many services, such as mobile communications, WBAN, WPAN, WLAN, and WMAN networks. In particular, the assessment of human exposure to radiofrequency field generated by handled devices communicating through wideband digital signals has become a topic of growing interest. Therefore several tools are available for measuring electromagnetic field [1] and the most popular are based on a diode detector [2]. In particular field probes [3] allows to obtain immediate readings and bands significant, but several studies have emphasized the limitations introduced by a diode detector in presence of modulated signals [4-5]. Typically a SAR exposure characterization is performed by means of probes implementing either bolometers or diode detectors. Some authors have recently demonstrated that the last ones exhibit limitations in terms of accuracy, when dealing with digitally modulated signals. Probes used for specific absorption rate (SAR) measurements are historically calibrated and used in presence of non-modulated signals, even if they can be employed also to measure high-bandwidth digital signals. Papers available in the literature demonstrate that SAR sensors can introduce even significant errors when W-CDMA signals are under test, [6]. In fact, such signals are characterized by high dynamics, a sharp temporal variability and a wide spectral occupation, which can result in the introduction of uncertainties on the field assessment. The present paper has the aim of analyzing the behavior of SAR probes in terms of field estimation accuracy, in presence of some of the most important wideband digital modulation employed in WBAN, WPAN, WLAN and mobile systems. In particular, an experimental set-up has been designed in order to evaluate the probes response in presence of direct sequence and frequency hopping spread spectrum (DSSS, FHSS) and orthogonal frequency-division multiplexing (OFDM) signals.

2. Experimental set-up

The characterization of SAR probes response has been performed in a controlled environment, obtained by the design of a specific experimental set-up, which make use of a rectangular metallic waveguide, as reported in Fig.1and Fig.2. In particular, the use of a waveguide, instead of a classic anechoic chamber, has permitted the generation of electromagnetic field with higher levels. In fact, the power generated inside the waveguide is in the range between -5 dBm and 30 dBm. The employed waveguide is designed to work in the D-band, to cover one of the most used frequency bands in wireless applications. The measured signals have been generated by means of a vector signal generator (Agilent Technologies E4438C) and further amplified by 40 dB using a linear amplifier. The signal injected into the waveguide has been also monitored, using directional couplers, by a vector spectrum analyzer

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(Agilent Technologies E4440 PSA). The waveguide is characterized by the presence of a hole, realized along its side wall, to allow the insertion of the SAR probe. Moreover, inside the waveguide, in correspondence with the hole, a box has been inserted, with liquid whose dielectric parameters simulate the human liver. Thus, the SAR probe has been inserted into the waveguide through the hole and dipped in the liquid, Fig. 3, in order to generate measurement conditions as similar as possible to the normal operational mode of such tool. The output of the SAR probe has been monitored by means of a digital multimeter.

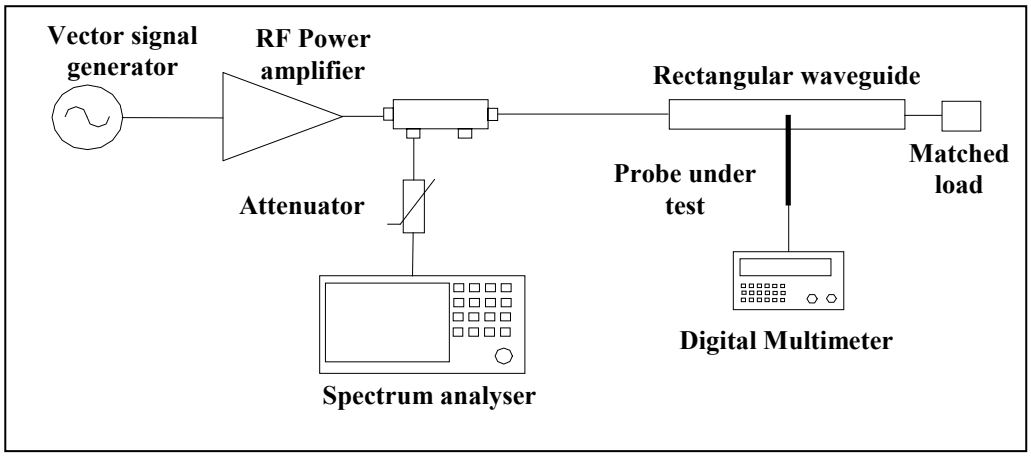

Fig. 1 : Experimental set-up. Overview of the measuring scheme

Fig. 2: Experimental set-up.

2. Measurements

The whole bunch of measurements has been performed on four different spread spectrum schemes: UMTS (W-CDMA), Bluetooth (FHSS), Wi-Fi 802.11b (DSSS) and Wi-Max 802.11e (OFDM). The different signals have been tested varying some modulation parameters and also generating frames with different filling.

First, the experimental set-up has been pre-characterized to take into account all the possible sources of uncertainties.

The presence of the hole may generate a variation of the electric currents along the waveguide walls, and consequently it has been necessary to take into account its effect in all the set-up characterization. In particular, has

been evaluated the possible impact of the hole and of the introduction of the sensor on the waveguide transmission and reflection coefficients. The performed measurements have demonstrated that the realized experimental set-up is reliable and adequate, as the insertion of the probe and the presence of the hole do not affect it in a sensible way, Fig. 4. However, other sources of uncertainty are still present, such as the RF generator, the RF amplifier, the impedance mismatch among the components and also the position of the probe, even if also these contributions have a neglectable impact on the overall measurement, since the outcome of the measurement is obtained by relative comparison. As well known, the probe is constituted by three dipoles oriented into three orthogonal directions, and thus it has been necessary to take into account the K-factor of each dipole. Such coefficients have been used to calculate the effective power incident on each probe dipole.

To evaluate the effective impact of the modulation on the probe measurement, the probe has been exposed first to a CW signal and then to a signal carrying the same power, but digitally modulated. The measurement has been kept coherent, maintaining the same frequency and the same field power density (controlled by the spectrum analyzer) and introducing variations just on the main modulation parameters. The evaluation of the uncertainty produced on the measurement has been fulfilled using a parameter called Modulation Additional Error (MAE) [7], that is calculated as the ratio between the output given by the probe in presence of the modulated signal (E_{mod}) and that obtained when the probe is exposed to the CW signal (E_{CW}).

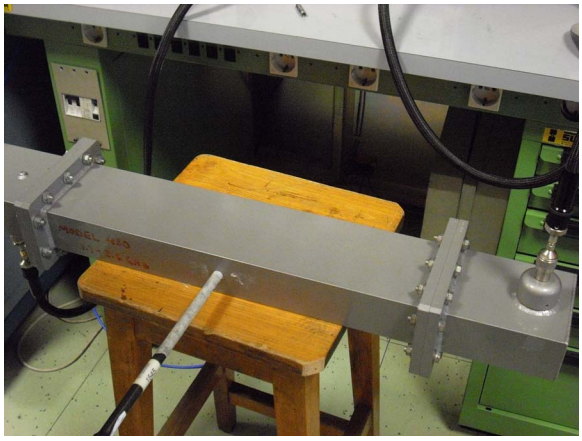

Fig. 3: The used D-band waveguide. The SAR probe is inserted into a hole on the side wall of the waveguide

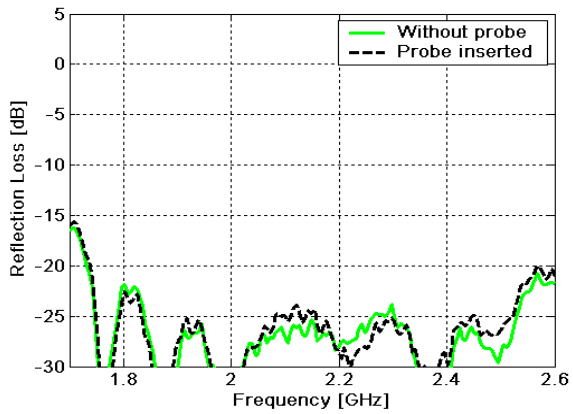

Fig. 4: Experimental set-up characterization: transmission and reflection coefficients

3. Results

The probes have been exposed to different modulations and each signal has been varied in terms of modulation parameters and frame filling. In this section the results related to OFDM modulation are reported, as the same behavior has been observed also for the other signals. The experimental result reported in Fig. 5 is referred to an OFDM full frame, whereas Fig. 6, Fig. 7 and Fig. 8 shows respectively OFDM frame for progressive levels of emptying of the frame (half, a quarter and 1/8). According to these results the probe introduces a overestimation in presence of full frame and generates an lighter overestimation as the frame becomes emptier and emptier. In particular for pulsed signal (Fig. 7 and Fig. 8) the SAR probe generates a quite constant result, introducing a really slight amount of overestimation.

5. Conclusion

The present paper reports the behavior of SAR probe, typically used with analogue signals, in presence of digitally spread spectrum modulations. The performed measurements confirm that such probe can introduce uncertainties that may affect dosimetric evaluations. In particular, overestimations depends on diode dynamic, as confirmed by the results obtained for different frame filling. In order to correct the introduced overestimation it would be preferable to pre-characterize the probe, at least for a set of known base signals.

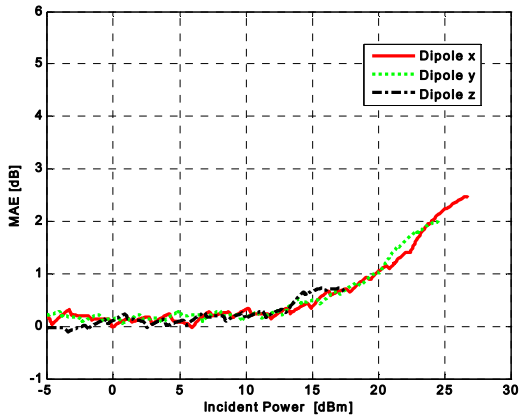

Fig. 5: Experimental results: E_{mod}/E_{CW} [dB] as a function of the incident power [dBm]. OFDM modulation,full-frame.

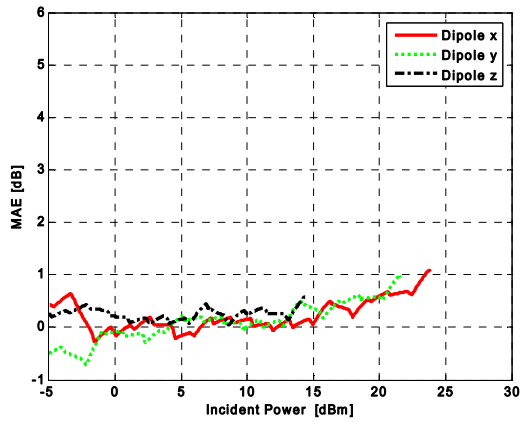

Fig. 6: Experimental results: E_{mod}/E_{CW} [dB] as a function of the incident power [dBm]. OFDM modulation,frame filled for 1/2.

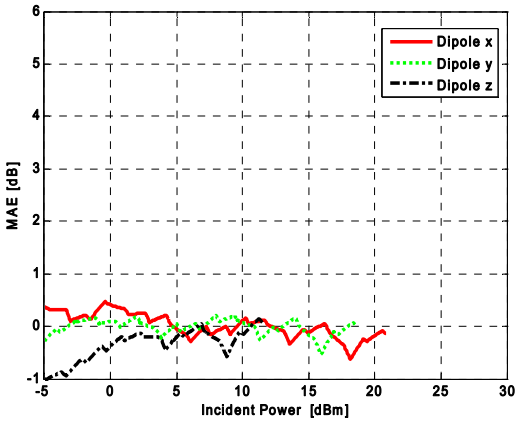

Fig. 7: Experimental results: E_{mod}/E_{CW} [dB] as a function of the incident power [dBm]. OFDM modulation,frame filled for 1/4.

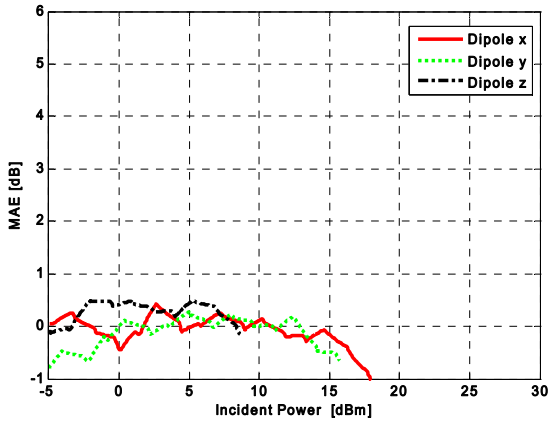

Fig. 8: Experimental results: E_{mod}/E_{CW} [dB] as a function of the incident power [dBm]. OFDM modulation,frame filled for 1/4.

7. References

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