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Review Article

Verification of Antenna Sensor with Commercial Handsets By Applying Radiative Calibration Method

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Abstract

This paper describes an antenna proximity sensor for mobile and applications based on the measured reflection coefficient using a bidirectional coupler. A bidirectional coupler which uses forward and reverse parameters is located between radiated antenna and RFFE (RF Front-End). The measured reflection coefficient proved high chances to act as an antenna sensor. The proposed antenna proximity sensor showed excellent performance and some of the test results with Samsung smartphone are attached to prove it.

Keywords: Antenna Sensor; Proximity Sensor; Reflection Coefficient; Samsung Smartphone

Introduction

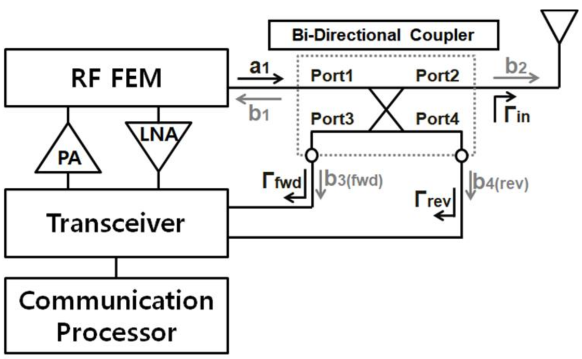
As the technologies for mobile evolve, many types of sensors have been deployed in a variety of products. Among the many sensors for mobile, the proximity sensor, which senses the existence of external objects, is one of the most essential sensors for various applications. Especially in the case of proximity sensor, the capacitive proximity sensor is widely used to recognize the hand-gripping and body-detecting condition of the mobile [1]. As an object approaches the proximity sensor, the sensor can detect the object using the measured capacitance from the sensor [2,3]. This is done by connecting a sensing probe from the sensor integrated Circuit to the main antenna, which could deteriorate the radiation performance.

In this paper, the proximity sensor, is proposed based on the measured reflection coefficient using a bidirectional coupler between RFFE (RF Front-End) and the antenna, is applied to Samsung commercial smartphone. The overall performances will be presented to validate its sensing ability as a proximity sensor for international regulation spec. It could replace the commercial proximity sensor and this study would be the start of considerable impact to any other mobile sensor.

Principle of the Antenna Proximity Sensor

(Figure 1) shows a block diagram of the antenna proximity sensor. The baseband signal is generated by the communication processor (CP) and is applied to the transceiver. Then, the transceiver up-converts the signal into the RF band which is radiated by the antenna through the power amplifier (PA) and RFFE. A bi-directional coupler is located between the RFFE and the antenna.

Figure (1): Block Diagram of antenna proximity sensor



The 4-port S-parameter of the bidirectional coupler is used to find the reflection coefficient looking into the antenna. The 4-port S-parameter of the bidirectional coupler is given by:

$$\begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{21} & S_{22} & S_{23} & S_{24} \\ S_{31} & S_{32} & S_{33} & S_{34} \\ S_{41} & S_{42} & S_{43} & S_{44} \end{bmatrix} \begin{bmatrix} a_1 \\ b_2 \cdot \Gamma_{in} \\ b_3 \cdot \Gamma_{fwd} \\ b_4 \cdot \Gamma_{rev} \end{bmatrix} \quad \textbf{(1)}$$

Where $\mathbf{a_n}$ and $\mathbf{b_n}$ are the incident and reflected signals for the n-th port of the coupler, respectively. $\mathbf{\Gamma_{in}}$ is the input reflection coefficient of the antenna. $\mathbf{\Gamma_{fwd}}$ and $\mathbf{\Gamma_{rev}}$ are the input reflection coefficients for the forward and reverse ports of the coupler, respectively. $\mathbf{b_3}$ and $\mathbf{b_4}$ can be obtained from (1) as follows:

$$b_3 = S_{31}a_1 + S_{32}b_2\Gamma_{in} + S_{33}b_3\Gamma_{fwd} + S_{34}b_4\Gamma_{rev} \quad \textbf{(2)}$$

$$b_4 = S_{41}a_1 + S_{42}b_2\Gamma_{in} + S_{43}b_3\Gamma_{fwd} + S_{44}b_4\Gamma_{rev} \quad \textbf{(3)}$$

Since the forward and reverse ports of the bidirectional coupler are in good match to the transceiver through 50 Ω, $\mathbf{b_3\Gamma_{fwd}}$ and $\mathbf{b_4\Gamma_{rev}}$ in (2) and (3) can be approximated as zero. It is assumed that if the isolation between the ports and the directivity of the coupler are large enough, $\mathbf{b_3}$ and $\mathbf{b_4}$ can be approximated as follows:

$$b_3 \approx S_{31}a_1 \quad \textbf{(4)}$$

$$b_4 \approx S_{42}S_{21}a_1\Gamma_{in} \quad \textbf{(5)}$$

By replacing $\mathbf{a_1}$ in (5) with $\mathbf{b_3}$ / $\mathbf{S_{31}}$ from (4), the input reflection coefficient of the antenna can be derived as follows:

$$\frac{b_4}{b_3} \approx \frac{S_{42}S_{21}}{S_{31}}\Gamma_{in} \quad \textbf{(6)}$$

$$\Gamma_{in} \approx \frac{S_{31}b_4}{S_{42}S_{21}b_3} = \frac{b_4}{S_{21}b_3} \quad \textbf{(7)}$$

where $\mathbf{S_{31}}$ and $\mathbf{S_{42}}$ are the same. Since we know $\mathbf{S_{21}}$ of the coupler, it can be changed constant value. The approximated value of $\mathbf{\Gamma_{in}}$ can be obtained from the ratio of the reverse coupled signal to the forward coupled signal [4,5].

Sensing Procedure

(Figure 2) shows the computational procedure used to detect SAR (Specific Absorption Rate) case need to power back-off, using the extracted input reflection coefficient of the antenna. First, the mobile determines whether it is necessary to use the antenna proximity sensor for reasons such as antenna impedance tuning or power control under the hand-gripping or body-detecting condition. If it is necessary, the mobile senses $\mathbf{b_3}$ and $\mathbf{b_4}$ from the forward and reverse ports of the coupler and calculates the reflection coefficient by using (7). And then, it could be changed into I/Q coordinates. As shown (Figure 3), there is the SAR case which includes 0mm, 2mm, up to 5mm, highlighted thick black circle. If it is collected $\mathbf{b_3}$ and $\mathbf{b_4}$ data, changed into I/Q coordinates and it is within this predefined area, mobile should conduct the power back-off to meet international regulation of SAR.

Figure (2): Antenna sensor algorithm to detect SAR case or not

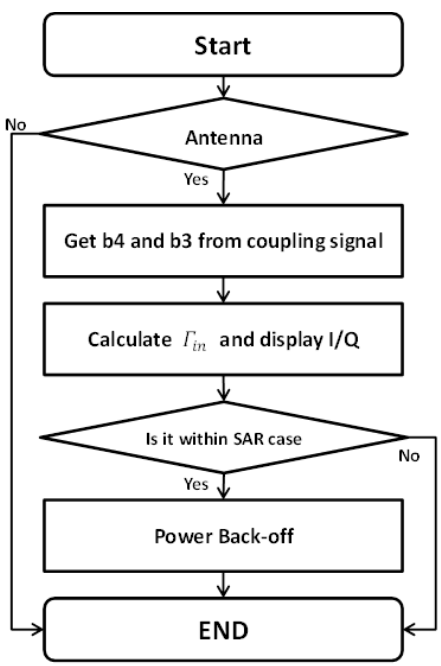


Figure (3): I/Q coordinate data and SAR case predefined area

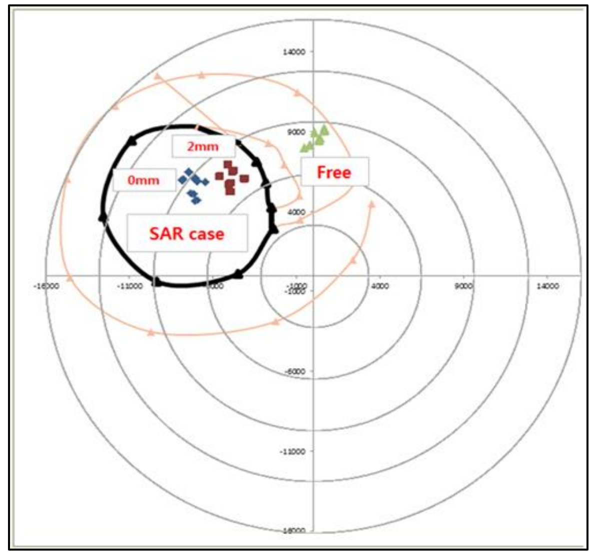
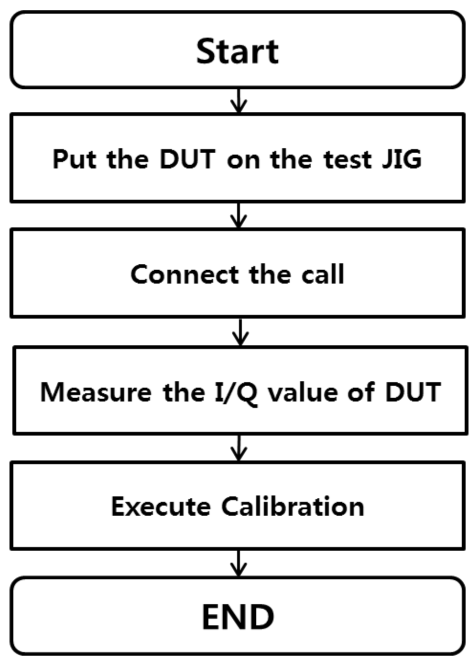
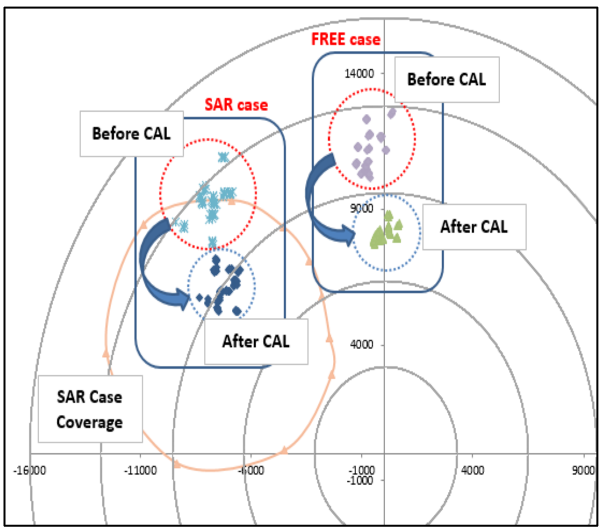


Figure (4): Antenna sensor calibration algorithm



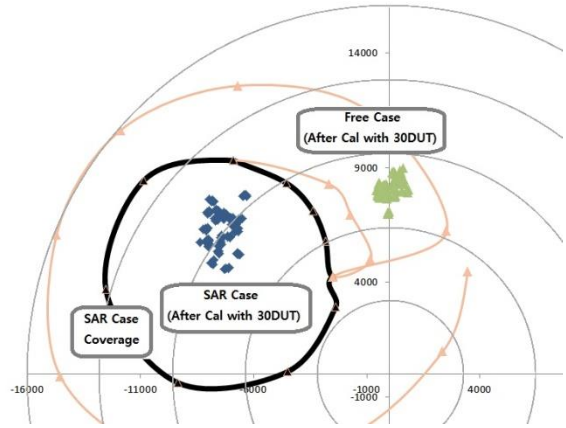
Before measuring performance of antenna sensor, calibration should be considered to improve the accuracy of sensor. (Figure 4) demonstrates the calibration algorithm for the antenna proximity sensor. Every DUT (Device Under Test) has their unique perform ance, and if the difference value between DUT is big, it can deteriorate the accuracy of antenna sensor and it could not make the role of it. So, it's needed to acquire more accurate sensor. I/Q results after calibration of 1DUT are shown as (Figure 5) during connecting the call in LTE band3. After calibration, I/Q results are changed to pre-defined target using the reference terminal. As a result, calibration to obtain offset value compared to reference was added to apply to all terminals on the same selection area.

Figure (5): I/Q results after Calibration of 1DUT in LTE Band3



After checking the calibration effect with many sets (30 DUTs), data scattered before calibration as shown in (Figure 6) are gathered at the pre-defined point through calibration and data variation is also improved.

Figure (6): I/Q results after Calibration of 30 DUTs in LTE Band3



Measurements Results

(Figure 7) shows the test setup for the antenna proximity sensor. The setup consists of a radio-communication analyzer, call box, and a phantom model (Speag's cSAR3D) which is the equivalent of using human tissues for testing purposes [5]. The LTE band 1, 2 and 3 signal, based on a quadrature phase-shift keying (QPSK) with a signal bandwidth of 20 MHz and 10 resource blocks, was applied for the test. Test results are shown as Fig. 8 and if it is within predefined trajectory which is named 'SAR case', it could conduct the power back-off. The international SAR limit of head and body for EU is under 2.0mW/g and DUT meets the SAR regulation without any problems.

Figure (7): Test setup for the antenna proximity sensor

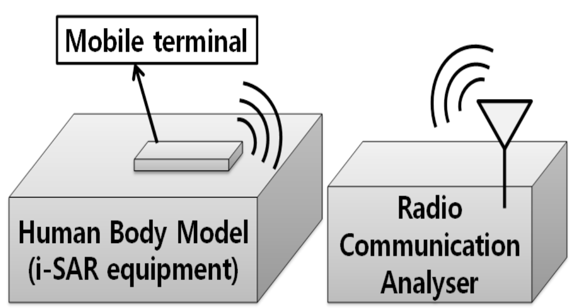
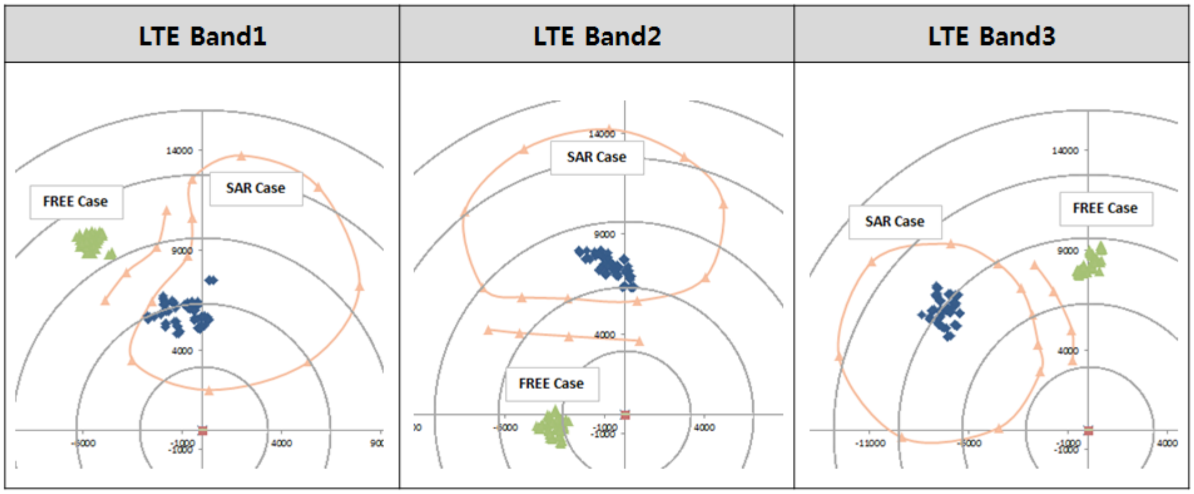


Figure (8): Test results of antenna sensor function and SAR of DUT in LTE Band1/2/3



SAR Measurement						
BAND	**Head/Body**	**Distance**	**1g/10g**	**Position**	**iSAR Head cSAR Body**	**SPEC**
Band1	HEAD	-	1g	Cheek	0.182	2.0 mW/g
		-	10g	Cheek	0.105	
	BODY	**5mm**	**10g**	**Front**	**0.869**	
Band2	HEAD	-	1g	Cheek	0.149	
	BODY	10mm	1g	Back	0.500	
	LIMB	0mm	10g	Back	1.029	
LTE_Band1	HEAD	-	1g	Cheek	0.250	
		-	10g	Cheek	0.146	
	BODY	**5mm**	**10g**	**Back**	**1.110**	
LTE_Band2	HEAD	-	1g	Cheek	0.202	
	BODY	10mm	1g	Back	0.709	
	LIMB	0mm	10g	Back	1.620	
LTE_Band3	HEAD	-	1g	Cheek	0.182	
		-	10g	Cheek	0.107	
	BODY	**5mm**	**10g**	**Back**	**0.992**	

Conclusion

In this paper, a newly noble antenna proximity sensor, which is based on the measured reflection coefficient using a bidirectional coupler between RFFE and the antenna, is proposed for mobile sensor and Samsung commercial sets are used for test. To prove this sensor and sensing algorithm, new calibration algorithm was introduced and applied.

The proposed sensor and algorithm shows that it can recognize the objects in the distance range of 0 to about 5 mm and if it is within predefined area, it can diagnose SAR case and decrease output power. The test results also show that its reproducibility is good and 30 DUTs are converged on predefined area after calibration.

More accurate algorithm and ability to diagnose longer distance are now being considered as an extension of the work.

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