Measured SAR of Integrated CMOS Transceiver Front End with Antenna Design

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***Abstract* –A Chromecast RFIC-on-chip antenna in 0.18 um CMOS process is presented. The measured VSWR is less than 2. The measured phase distribution of the input impedance is quite linear and the H-plane patterns are almost omnidirectional with power amplifier and low noise amplifier integration. This design includes a external broadband amplifier embedded with low-pass filter. The frequency-domain scattering parameters are converted into representations by employing weighted linear least square (LLS) method. A least square scheme is employed to obtain characteristic impedances of transmission line elements that form the amplifier having flat gain in the pass-band and good fall-off selectivity in the stop-band. RFIC-on-chip chromecast antenna also merger T/R switch and transceiver front end design on single chip solution for wearable technology application. Experimental results are presented to illustrate the validity of proposed design method.**

***Index Terms* —chip antenna, propagation, EM wave theory, AP-related topics.**

I. INTRODUCTION

The 2.4GHz CMOS RFIC on-chip antenna merger T/R-switch, power amplifier and low noise amplifier design for wireless application as shown Fig. 1. The low power transceiver develop insertion loss low and FET based T/R switch is more importance.

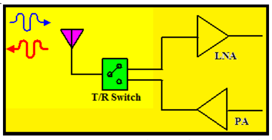

Fig. 1. The proposed CMOS transceiver front end design with antenna

II. CHROMECAST RFIC-ON-CHIP ANTENNA

The proposed 2.4-GHz RFIC-on-chip antenna is 1.21 (1.1mm×1.1mm) mm^2 with T/R-switch in 0.18 um CMOS process and based on the mender line by loop type as shown Fig. 2 (a). The T/R-switch is expected to be integrated with the front-end circuits into the chip that area is 0.15mm x 1.1mm as shown Fig. 2 (b). Switching radiation pattern is demonstrated such that the fading effect due to multipath propagations could be avoided as shown in Table1.

Table 1 Radiation Patterns of XY-Plane, XZ-Plane, YZ-Plane at 2.4 GHz

XY plane	*Max*	*Min*	*Average*
E_ϕ gain (dBi)	-43.2	-38.7	-53.2
E_θ gain (dBi)	-61.4	-89.8	-67.4

Xz plane	*Max*	*Min*	*Average*
E_ϕ gain (dBi)	-44.4	-53.0	-49.4
E_θ gain (dBi)	-40.9	-66.9	-46.1

Xz plane	*Max*	*Min*	*Average*
E_ϕ gain (dBi)	-39.1	-41.4	-40.5
E_θ gain (dBi)	-49.6	-80.0	-56.1

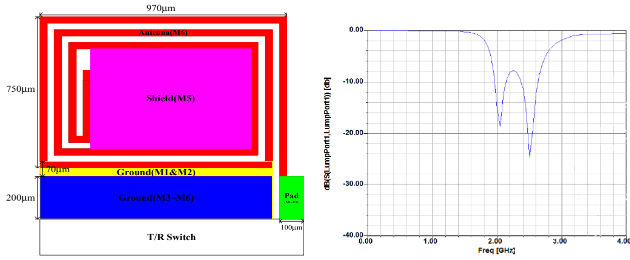

Fig. 2 (a) Layout of 2.4 GHz CMOS RFIC On-Chip Antenna and T/R-Switch (b) Measured RFIC-on-Chip combo antenna VSWR.

After design simulation T/R-Switch circuit and performance as shown Fig. 3, Fig. 4 and Table 2.

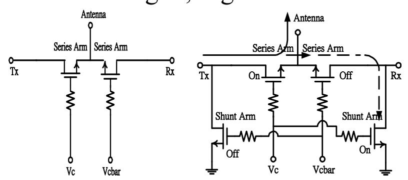

Fig. 3 T/R Switch architecture diagram and schematic

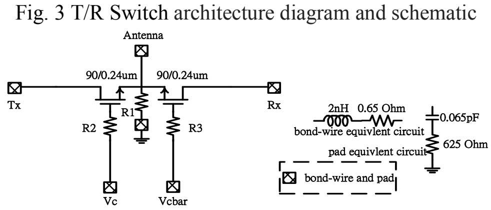

Fig. 4 T/R Switch circuit and layout

Table 2 T/R Switch characteristics table

T/R Switch: Characteristics	
Control Voltage	1.8V
Insertion loss	<1.0dB
Input return loss (Tx and Rx modes)	>12dB
Input P_{1dB} (Tx and Rx modes)	>21dBm
Isolation (Tx-Rx in Tx mode)	>24dB
Isolation (ANT-Tx in Rx mode)	>18dB

III. LOW NOISE AMPLIFIER DESIGN

Fig. 5 shows the circuit schematic of the two-stage broadband CMOS LNA. Design of the first stage mainly focuses on noise figure. From, the width of *M1* is chosen due to its minimum thermal noise contribution. A broadband-type filter (formed by *Ca*, *Lb*, and *Lc*) is utilized at input to achieve 2.4-GHz impedance matching.

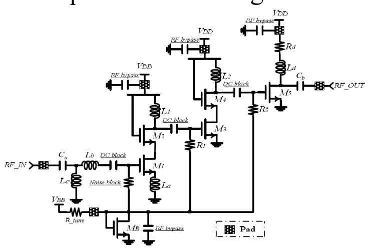

Fig. 5 The proposed LNA.

Because of little components for input matching, common-gate transistor is chosen as input device. The resonant frequency of inductance and the parasitic capacitance is chosen at 2.4 GHz for well input matching. The last stage uses single common-source transistor and RF choke for large output voltage swing, while output current swing is small due to output matching network. A broadband noise-canceling LNA for receiver is implemented in CMOS technology. Measured *IIP*3 agrees well with simulation and hand calculation .

IV. BROADBAND AMPLIFIER

The trend to achieve higher speed will continue [1]-[2]. Microwave passive component design using the discrete-time method had been proposed [3]-[4]. A least square approximation was employed to convert the scattering parameters into rational functions of angular frequency with 27 coefficients [5]. An L-band power transistor FSX017LG [6] is employed to study the conversion of scattering parameters from frequency-domain to discrete-time-domain representations. [4] shown the chain-scattering parameter matrices of basic transmission lines, namely, series line, shunt-open stub, shunt-short stub, and shunt-open two-section stub. The stability factor μ [8] of FSX017LG. The scattering parameters had been studied by rational functions of angular frequency in continuous domain [6]. The orders of both numerator and denominator terms are rather large, which can cause numerical noise at high frequency [7]. It is anticipated that the parallel form has lower orders of polynomials and causes less numerical noise [8].

V. MEASURED RESULTS

The proposed CMOS transceiver front end design with antenna builds in Tablet PC to measure SAR problems. The setup condition including robot, phantom, tissue simulating liquids and illustration for lap touching position is shown in Fig. 6. The setup tissue simulating liquids is shown as Table 3. The measured condition are 802.11b frequency is 2442MHz, σ=1.84mho/m; ε_r=39.3; ρ=1000kg/m^3; ambient temperature=22.5°C; liquid temperature=21.5°C. This design SAR measured results are shown as Table 4 that can meet CE requirement.

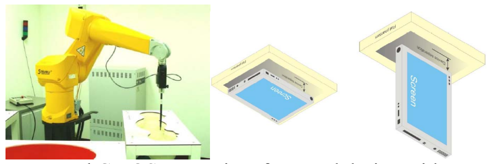

Fig. 6 The proposed CMOS transceiver front end design with antenna builds in Tablet PC for SAR testing.

Table 3 The setup tissue simulating liquids

Recipes of Tissue Simulating Liquid

Frequency (MHz)	Water (%)	Sugar (%)	Cellulose (%)	Salt (%)	Preventol (%)	DGBE (%)	Conductivity (σ)	Permittivity (ε_r)
2450	55.0	0	0	0	0	45.0	1.80	39.2

Targets of Tissue Simulating Liquid

Frequency (MHz)	Conductivity (σ)	±5% Range	Permittivity (ε_r)	±5% Range
2450	1.80	1.71 ~ 1.89	39.2	37.2 ~ 41.2

Measuring Results for Simulating Liquid

Frequency (MHz)	Liquid Type	Temperature (℃)	Conductivity (σ)	Permittivity (ε_r)
2450	Head	21.5	1.85	39.3

Table 4 This design SAR measured results

<WLAN>

Band	802.11b			802.11g		
Channel	1	7	13	1	7	13
Frequency (MHz)	2412	2442	2472	2412	2442	2472
Avg.Power	15.96	16.05	16.22	15.65	15.70	15.80

Band	802.11n (BW 20MHz)		
Channel	1	7	13
Frequency (MHz)	2412	2442	2472
Avg.Power	12.96	13.11	13.45

Band	Bluetooth		
Date Rate	2DH5		
Channel	1	7	13
Frequency (MHz)	2412	2442	2472
Avg.Power	6.38	7.02	7.31

Plot No.	Band	Mode	Test Position	Separation Distance (cm)	Channel	Ear-phone	SAR_{10g} (W/kg)
1	802.11b	-	Bottom Face	0	7	v	0.298
2	802.11b	-	Primary Landscape	0	7	v	0.008
3	802.11b	-	Secondary Landscpe	0	7	-	0.06
4	**802.11b**	**-**	**Primary Portrait**	**0**	**7**	**v**	**0.486**
5	802.11b	-	Secondary Portrait	0	7	v	0.00613
6	802.11g	-	Primary Portrait	0	7	v	0.412
7	802.11n	BW 20MHz	Primary Portrait	0	7	v	0.205

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