



Wireless Power Transfer and Communication to a Miniature Sensing RFID for Defense

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Driving Applications: Supply Chain Hardware Integrity for Electronics Defense (SHIELD)

Our Safety Built On Electronics Threatened

Counterfeit chips plague Pentagon weapons systems

Florida case turns up embedded parts from China destined for nuclear, advanced military and missile

By M. J. Healy, 10/18/06, 10:00 AM

U.S. Attorneys - District of Connecticut - News And Press Releases

Department of Justice
U.S. Attorney's Office
District of Connecticut

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Citizen of China Sentenced to 15 Months in Prison for Trafficking in Counterfeit Computer Chips

Dwight M. Daly, United States Attorney for the District of Connecticut, announced that Daoxi Zhang, 40, of Shenzhen, China, was sentenced today by U.S. District Judge Robert N. Chutkan in Hartford to 15 months of imprisonment for conspiring to sell counterfeiters of sophisticated integrated circuits to a purchaser in the United States.

Types of Counterfeits

Source: Defense Systems Information Analysis Center

DARPA SHIELD (Supply-chain Hardware Integrity for Electronics Defense)

- 0.01mm² tag (with antenna) on critical electronics
- Probe/Reader 1mm away (Inductive power transfer)
- Report host identity and unusual activity (Uplink/Sensor)

Image source: DARPA

First Prototype: A 5.8 GHz Power-Harvesting Diode with On-Chip Coil Antenna (18' ISSCC)

0.01mm² tag

Image source: Northrop Grumman

Near-Field Radio Chip

Downlink: $f_1=f_2$, Uplink: $f_1 \neq f_2$

IM2: f_1-f_2

IM3: f_1+f_2

On-Chip Antenna

Bandgap, PoR, AC-DC, ASK Detector, Manchester Decoder, Digital Authentication, TXEN, Switch-Controlled Decap#1, 4kHz Clock Generator, 4kHz Clock, EB-Written Memory, 4Kbps Data, Carrier Oscillator, IM2+ f_1 , IM2+ f_2 , Injection-Lock

Power Combiner, PA#1, PA#2, Downlink: Manchester coded 8-bit Authentication Data, Uplink: Constant "V_{cc}"

□ Coupling distance at 1.0mm

□ 5.8-GHz RF power = 32 dBm, $dc = 10\mu W$

□ 4kb/s UL with the proposed **IM3 UL** (17' MWCL, 17' TMTT)

- Two-tone Tx (5.728/5.768 GHz) excites the rectifier IM3 current at 5.808 GHz
- IM3 current modulated by the tag baseband signal (a new UL channel)
- Closely-separated Tx/Rx frequencies allows passive reuse
- Tx/Rx frequency separation allows utilization of a duplexer for a clean Rx

5.805-5.850 GHz (Port#3), 5.725-5.770 GHz (Port#1)

Reader & "Diode", Duplexer / Probe Station

System Optimization and Range Extension with a Differential Reader Coil (18' T-MTT)

- Analytical expression for IPT PTE developed (variables: coupled-coils geometries, frequency, rectifier stages, material properties)
- Differential (DF) coil shown to be more efficient than single-ended coil
- "EM-less" (simulation) numerical optimization locates the optimal design rapidly
- Best PTE: 4.7-GHz, 33-dBm RF power at **2.2-mW** (PTE = 50ppm)

DF and SE Reader Coils

50-Ω T-line, 33 dBm, MNW, Coil, 4 mm

50-Ω T-line, > 10 W, MNW, Coil, 4 mm

50-Ω T-line, > 10 W, MNW, Coil, 3 mm

Rectenna harvested $dc = 0.1 mW$

CMOS Rectenna

100 μm, Vbia, Gnd, Vout

REPORTED IPT PERFORMANCE WITH A MINIATURE TAG (TAG SIZE < 0.2 mm²)

Ref.	Tag Coil (mm ²)	Dist. (mm)	RF Freq. (GHz)	Power into Coil (mW)	dc Power (mW)	RF-RF Eff. (dB)	RF-DC Eff. (dB)	IPT FOM	Tx Coil	PA	Reader Substrate	Integration Level
13' JSSC	0.13	1.0	1.5	17	0.01	N.A	-37	-24	2-Coil	CW	FR4	CMOS Rectenna
16' IMS	0.04	1.1	2.0	21	0.1	-29 (Sim)	-31	-9	2-Coil	CW	FR4	CMOS Rectenna
12' CICC	0.014	0.05	3.5	22	13.7	N.A	-10	-21	2-Coil	CW	Silicon	CMOS Rectenna
16' MWCL	0.01	1.2	4.7	31	0.1	-39 (Sim)	-41	-9	2-Coil	CW	FR4	CMOS Rectenna
16' IMS	0.01	0.5	2.0	N.A	N.A	-27	N.A	N.A	3-Coil	CW	High-R Si	Coils only
17' IMS	0.01	0.5	2.5	20	0.14	N.A	-29	-8	3-Coil	CW	Glass	Discrete Rectifier
This Work	0.01	2.2	4.8	33	0.1	-41 (Sim)	-43	-3	2-Coil	CW	Rogers	CMOS Rectenna

*IPT FOM = (Eff.)² Dist.³ Tag Coil Area^{-1.5}

IM3 UL Adopted to Far-Field Commercial RFID System (18' MWCL)

910MHz SG, 910/890MHz, 910MHz: 19dBm (DL session); 22dBm (UL session); 890MHz: Off (DL session); 6dBm (UL session)

20 cm

930MHz, 48 dB, -7 dBm, 10-MHz REF, 10MHz REF, Att, RF Switch, PA, Duplexer, Mixer, Amp, SG 890MHz, BB

- Improving reader performance communicating to a commercial UHF tag (Monza 6)
- Asymmetric two-tone Tx (910/890 MHz) in UL session
- Decoded IM3 UL EVM (w. square demod.) = -20 dB
- Decoded Backscattering UL EVM (w. IQ demod.) = -14 dB

Conventional Backscattering UL

IM3 UL

Decoded Data, Decoded Data, Decoded Data

Passive Temperature Shock Recording Sensor (18' MEMS)

(a) Ag⁺ film (nonconductive)

(b) Ag nanoparticles

(c) Ag conductors

Reduction agent, Heat, Ag⁺ film, Ag nanoparticles, Ag conductors

- Heating-induced reduction of silver-ions in a polymer film
- Sheet resistance irreversibly drops 4 orders of magnitude in a heating process.
- Deposited to R-sensing IC using high-precision electrohydrodynamic deposition technique

Deposited Strip: lengths = 200μm, diameter = 30μm

Heating @ 300°C, Room Temperature

Chip VDD, Sensor Pad, GND, clk, reset, q1, q2, q3, 3-bit digital output (LED amp)