Feasibility of printing RFID antennas on corrugated paperboard

by
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San Antonio, TX
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Agenda

- **Background**
- **Research:** identify problem
- **Study Topic and Objective**
- **Experimentation I:** methodology and result
- **Experimentation II:** methodology and result
- **Conclusion**
- **Further Studies:** the related topics
- **Dedication**

Background

Why Printed-RFID on Corrugated?

- RFID Trend in Packaging Business
- Corrugated Packaging Business
- Personal Inspiration

RFID Trend in Packaging Business

Wal-Mart's RFID Mandate

"The world's largest retailer asked *all* suppliers to put RFID tags on pallet and cases by 2006."

★ **Estimated 4 billion tags per year** ★

RFIDJournal, 2004

Plus:

DoD (USA)

Tesco (UK)

Metro AG (German)

RFID Mandate

WAL★MART ALWAYS LOW PRICES. Always.
DEPARTMENT OF DEFENSE
AUTO-ID CENTER
THE HOME DEPOT
P&G
PHILIP MORRIS INTERNATIONAL
TESCO
INTERNATIONAL PAPER
Johnson & Johnson
Unilever
Carrefour
Coca-Cola
The Gillette Company
PEPSICO
UNITED STATES POSTAL SERVICE
METRO

RFID Trend in Packaging Business

Why can't we say "No" to Wal-Mart?

- **No.1 largest private employer in USA with 1.3 million employees**
- **138 million shoppers per week; $8,126 in sales per second**
- **Wal-Mart sells in 3 months = Home Depot sells in 1 year**

Top 10 Retailers Worldwide

Rank Retailer Sales in US Dollars ($Mil)

1	**Wal-Mart Stores, Inc.**	**$163,532.0**
2	Carrefour Group	$52,196.1
3	The Kroger Co.	$45,352.0
4	Metro AG	$44,163.4
5	The Home Depot, Inc.	$38,434.0
6	Albertson's, Inc.	$37,478.0
7	ITM Enterprises SA	$36,762.5
8	Sears, Roebuck and Co.	$36,728.0
9	K mart Corporation	$35,925.0
10	Target Corporation	$33,702.0

Source: PricewaterhouseCoopers, 2000

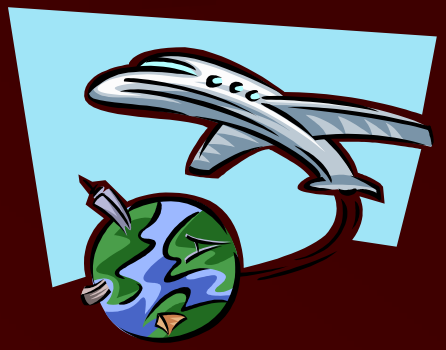
Future Packaging

(With RFID tag)

They are all smart!

Corrugated Packaging Business

"Growing Demand in Asia"



- **Trend: Off-shoring to Asia**

  (Outsourcing)

- **<u>Corrugated</u>: Packaging for Distribution**




Corrugated Packaging Business

Don't you think, We should be ready?

(Converters)

One day Manufacturers will ask,
"Put it (RFID) in, save me the cost
and save me the trouble"

(Mark Roberti, 2004)

Personal Inspiration!

6+ years experience in

"corrugated packaging business"

brought to an interest in

New Technology to Implement in Corrugated Industry

Research

Research on RFID in Packaging Industry

- **Implementation situation: high cost, lack of know-how, very little implementation**
- **Market's requirement: low coat RFID**
- **Packaging industry's awareness: ability to provider RFID with competitive price**

Research

Research on RFID in Packaging Industry

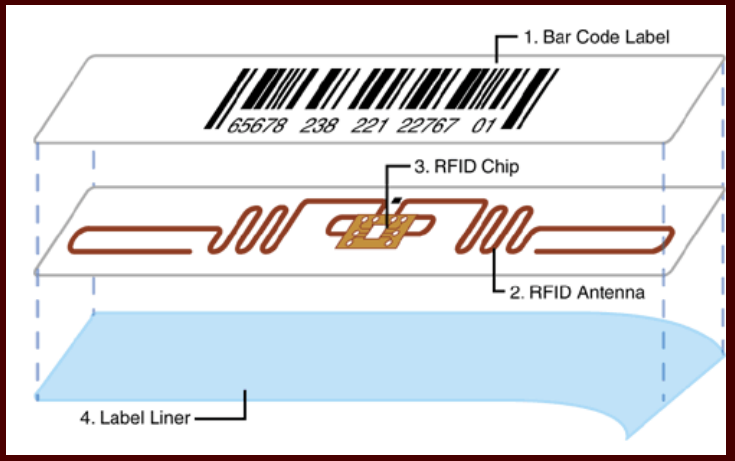
- **Existing application**
  - **Applied Labels (Slap and Ship) : Slow & costly**
  - **Placed Inlays : expensive & insecure**
  - **Integrated RFID : high investment & lack of know-how**
- **Innovation of conductive ink for “Printed RFID”**
- **No published information found on “Printed RFID” and “Corrugated”**

Type of RFID for Packaging

RFID tags for Packaging

- **Conventional RFID : Copper antenna on label**
- **Printed RFID: Printed antenna with conductive ink**
  - **On Label**
  - **On Package or Product**

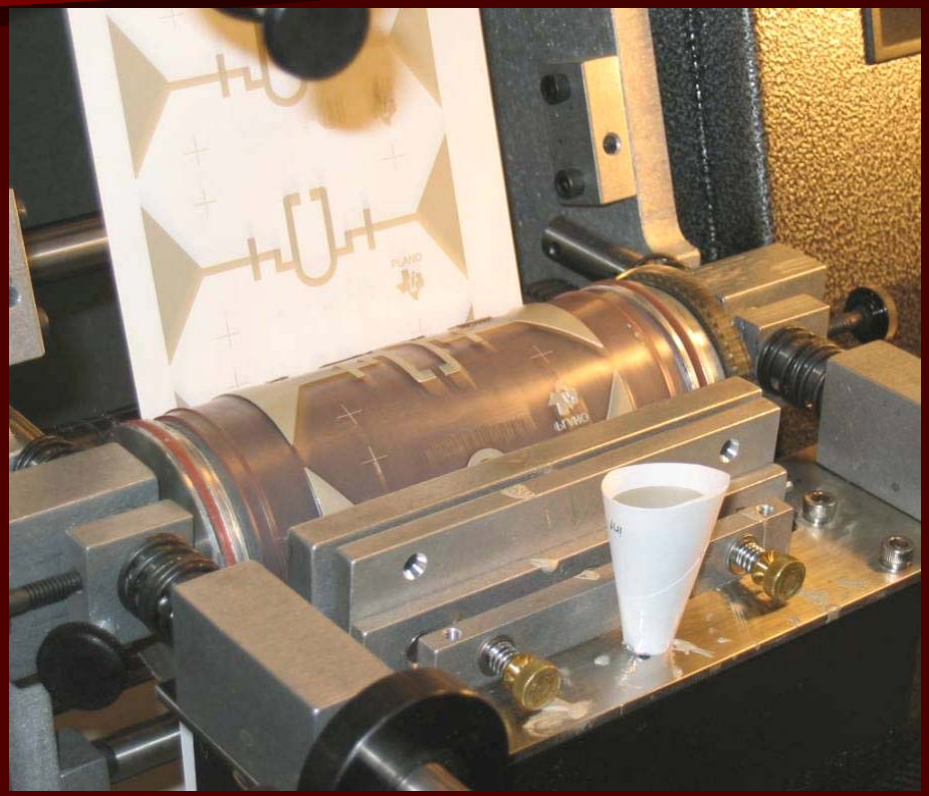
    (Integrated RFID)



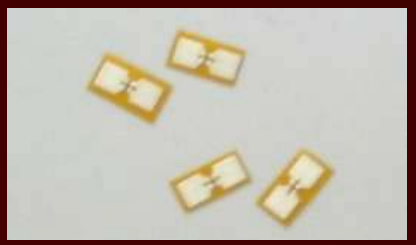
RFID Journal, 2005

Type of RFID for Packaging

Printed RFID on Packaging



Antenna Printing Process on Labels



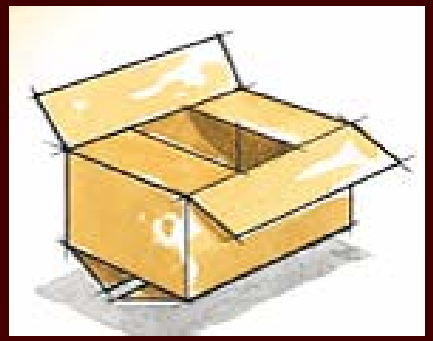
RFID Microchip

Strap-attach-based Microchip

www.rfidproductnews.com, 2005

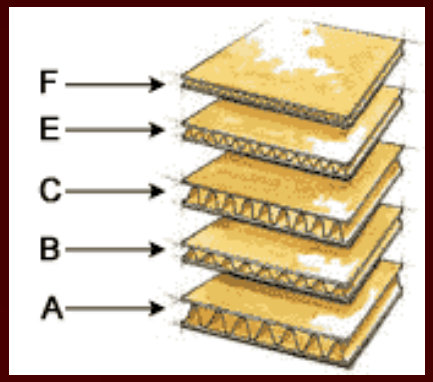
RFID for Corrugated?

Possibility to apply Integrated RFID on Corrugated?



Limitations of corrugated on print quality:

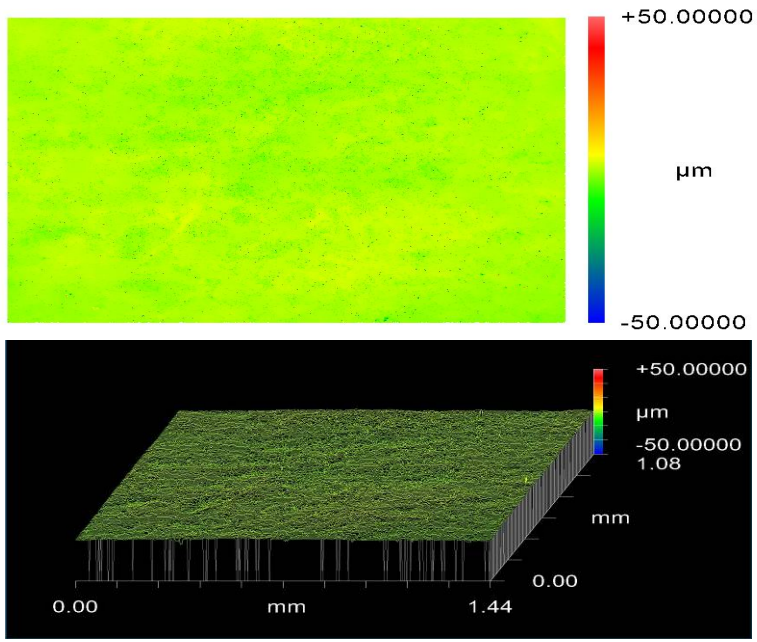
- **Surface Roughness**
- **Flute Stripes**



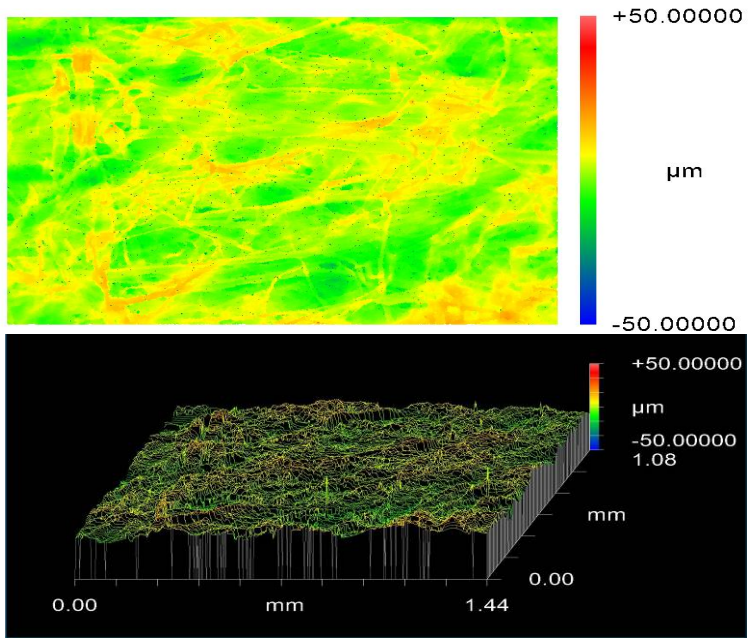
www.fibrebox.org

Surface Roughness Comparison

Tester: **Zygo NewView 200 Profilometer and Parker Print-Surf Roughness Tester**



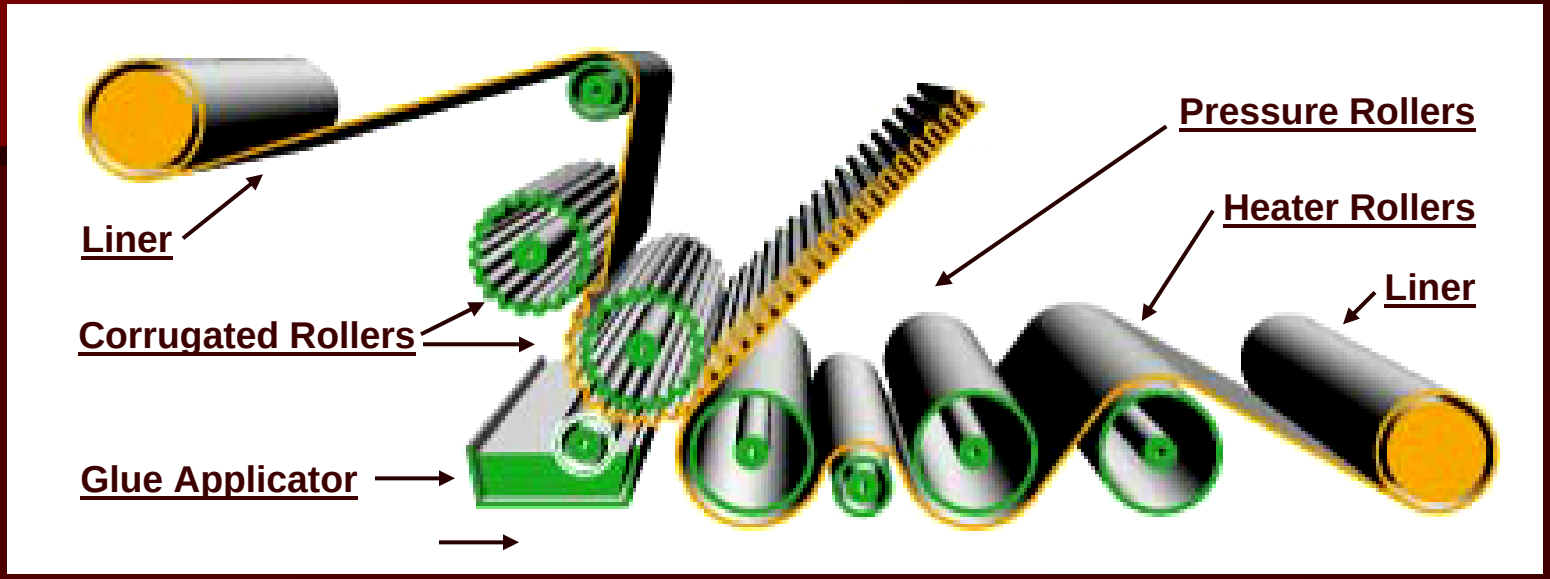
Coated Paper (Sappi)

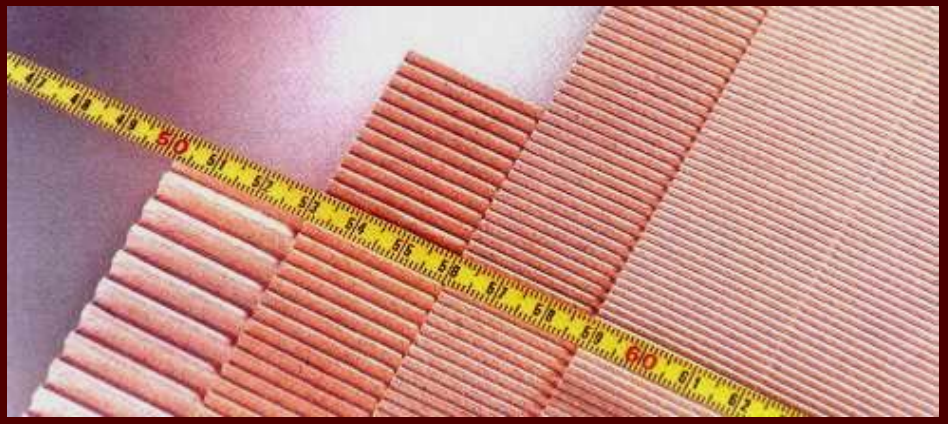


Kraft Paper (TCG)

Surface Roughness	Coated (µm)	Kraft (µm)	Diff.
Ra	0.72 – 0.78	4.20 – 5.20	85%
Parker Print-Serf	0.95 - 1.00	7.60 - 7.86	87%

Flute Stripe Effect





Study Topic and Objective

Topic: **Feasibility of Printing RFID Antennas on Corrugated Paperboard**

objective:

- **determine the technical feasibility of printing RFID antennas directly on kraft-corrugated**
- **identify the possibility of using the functional RFID antennas in severe environment**

Study Topic and Objective

Topic: **Feasibility of Printing RFID Antennas on Corrugated Paperboard**

Experimentation:

- **Section I** **Conductivity of the Printed Antennas**
- **Section II** **Performance of Functional Antennas under Severe Environments**

Experimentation

Equipment:

IGT F1 Printability Tester:

Flexography Proving-scale Printer

Printing Speed: 20 ml/m²

Anilox Volume: 0.3 m/s

Fluke 87:

rms Multi-meter

Environmental Controlled Chamber

Science TempTM:

Freezer

Experimentation

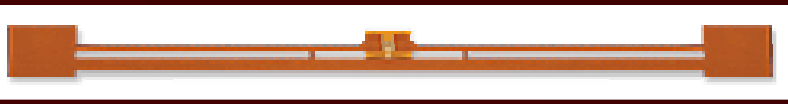
Materials:

- **Substrates**
  - Coated Paper:10 mils (Sappi)
  - Kraft Paper: KI 185, 38 lb/1000 sq.ft. (TCG)
  - Corrugated E-flute: KI185/CA125/KI185 (38/26/38) (TCG)
  - Corrugated B-flute: KI185/CA125/KI185 (38/26/38) (TCG)
  - Corrugated C-flute: KI185/CA125/KI185 (38/26/38) (TCG)
- **Conductive Ink**: Precisia CFW-104, Water-based silver ink

Experimentation

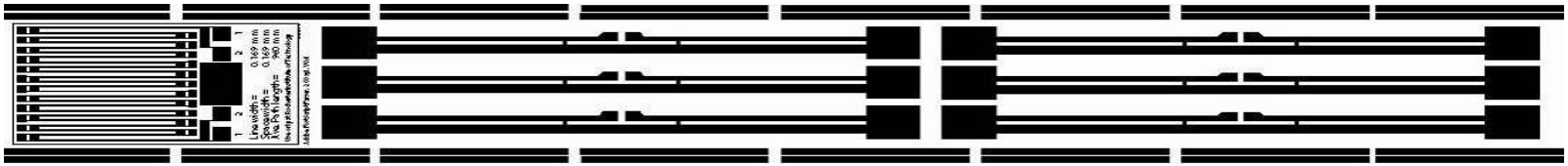
Materials:

- **Antenna Style: Alien's I2**



- **Printing Plate/Pattern:**

  Dupont's Cyrel, Flexographic polymer



Test Target Antennas Antennas

Experimentation Preparation

Experimentation I: Conductivity of the printed antenna

Test Parameter: **Electrical Resistance (Ω or Ohm)**

Find the proper inking force

Find an optimal printing condition for each substrate (printing pressure & speed)

Print antennas on each substrate using the best printing conditions

Measure and Compare

Measure Commercial Labels for Printability Evaluation

Test Specimens:

Coated Paper | **Kraft** Paper | **E-flute** Corrugated | **B-flute** Corrugated | **C-flute** Corrugated

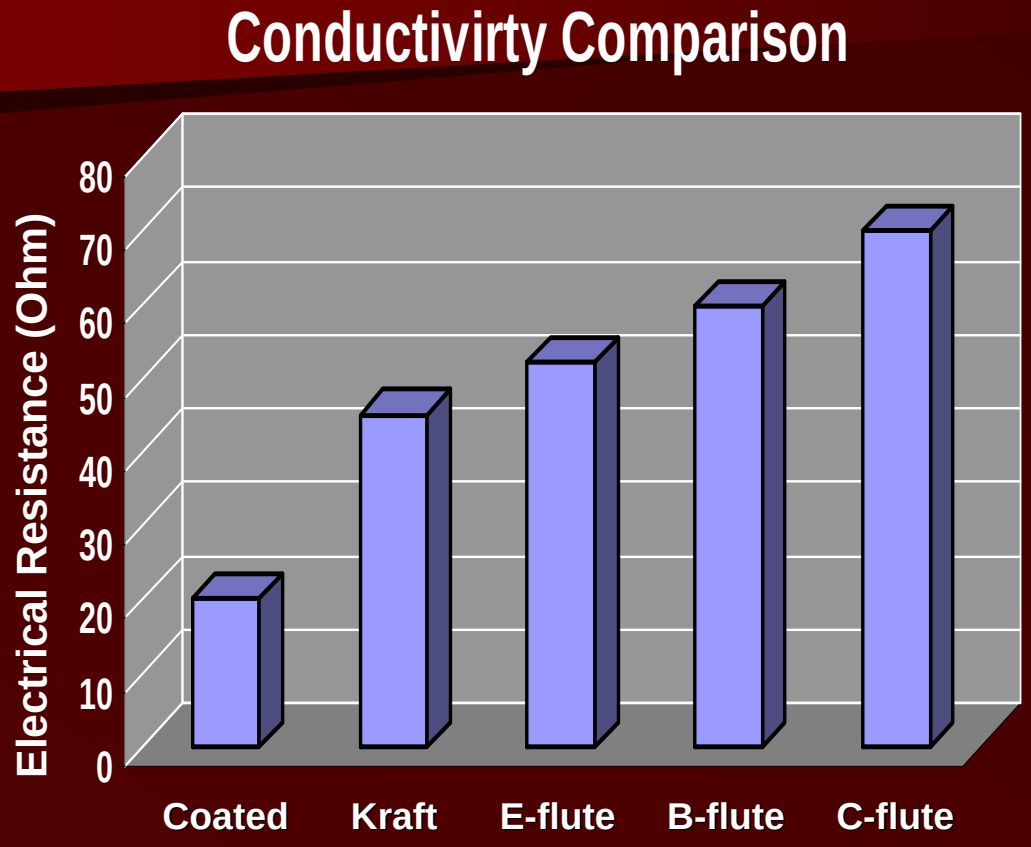
Experimentation I

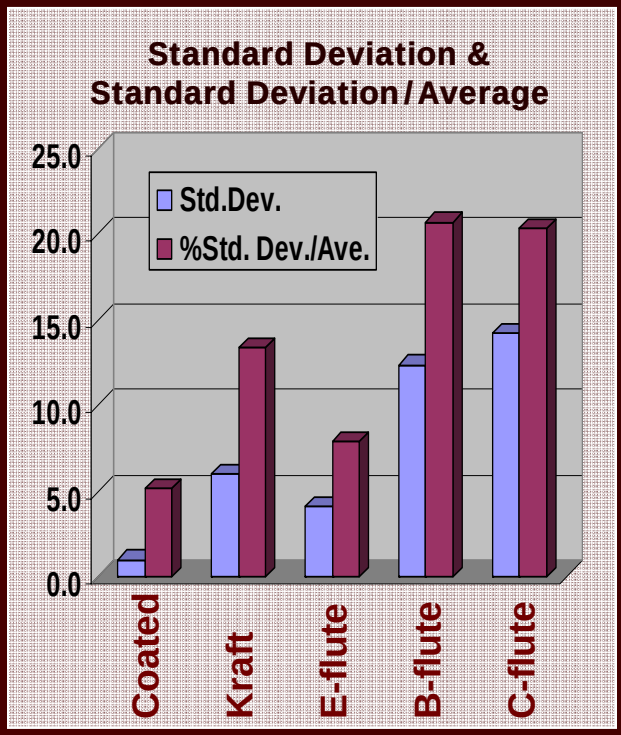
Test Result : Printing Condition Tests for Each Substrate

Discussion: When printing condition changed;

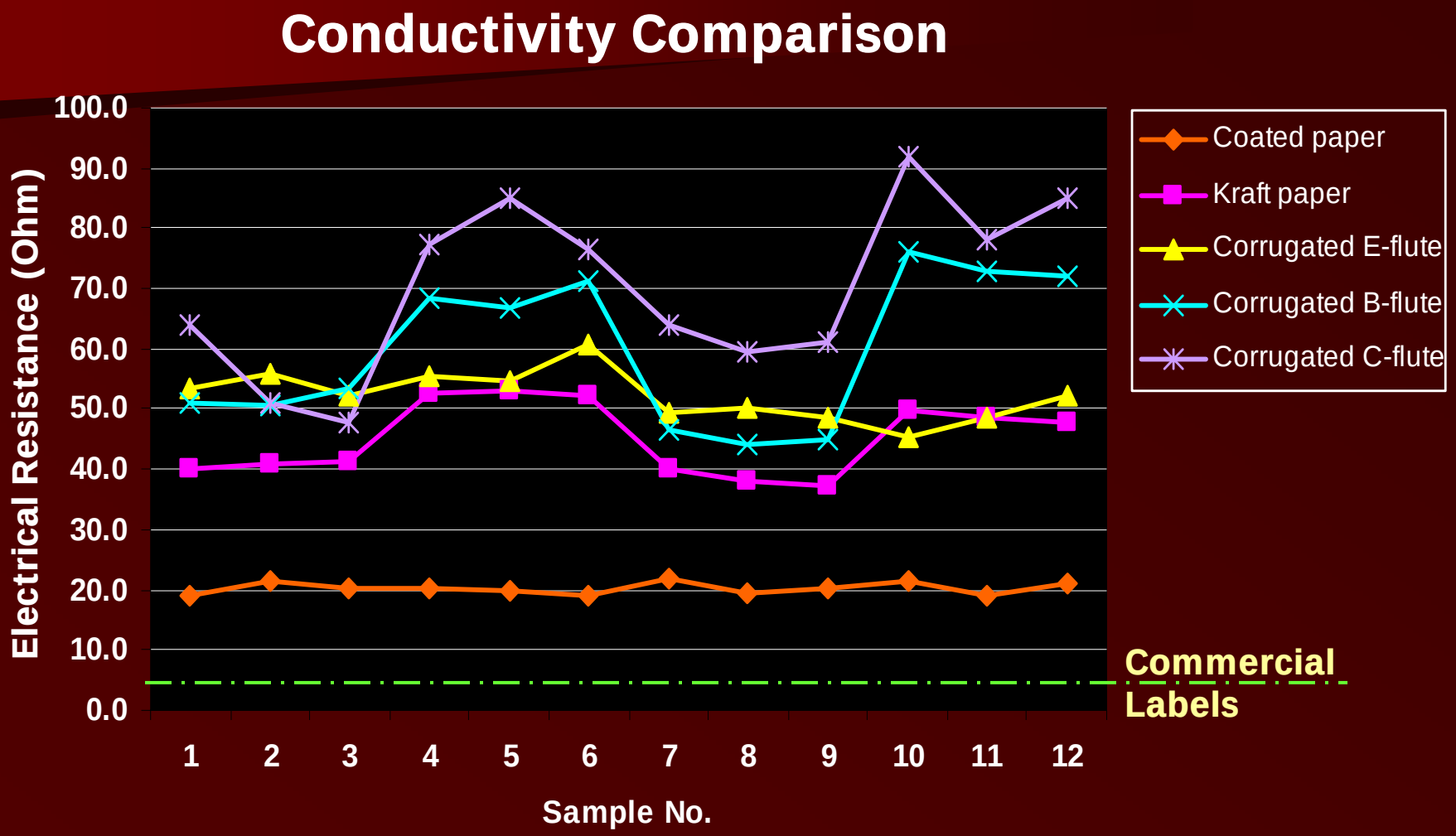
- Conductivity on Coated Paper slightly changed
  - Higher pressure: higher conductivity
  - Higher speed: lower conductivity
- Conductivity on Kraft Paper & E-flute had bigger change, but in same direction
- Conductivity on B-flute & C-flute was fluctuated with no accordance to pressure & speed

Test Result : Conductivity Measurement & Comparison





Test Result : Conductivity Measurement & Comparison



Experimentation I: Conductivity of the printed antenna

Discussion:

- The variability in conductivity of kraft paper and corrugated substrates might be caused by the physical properties of materials: flute-profile, gap between liners, and flute-stripes.
- Among corrugated substrates, flute-profiles directly affected the quality of antennas.

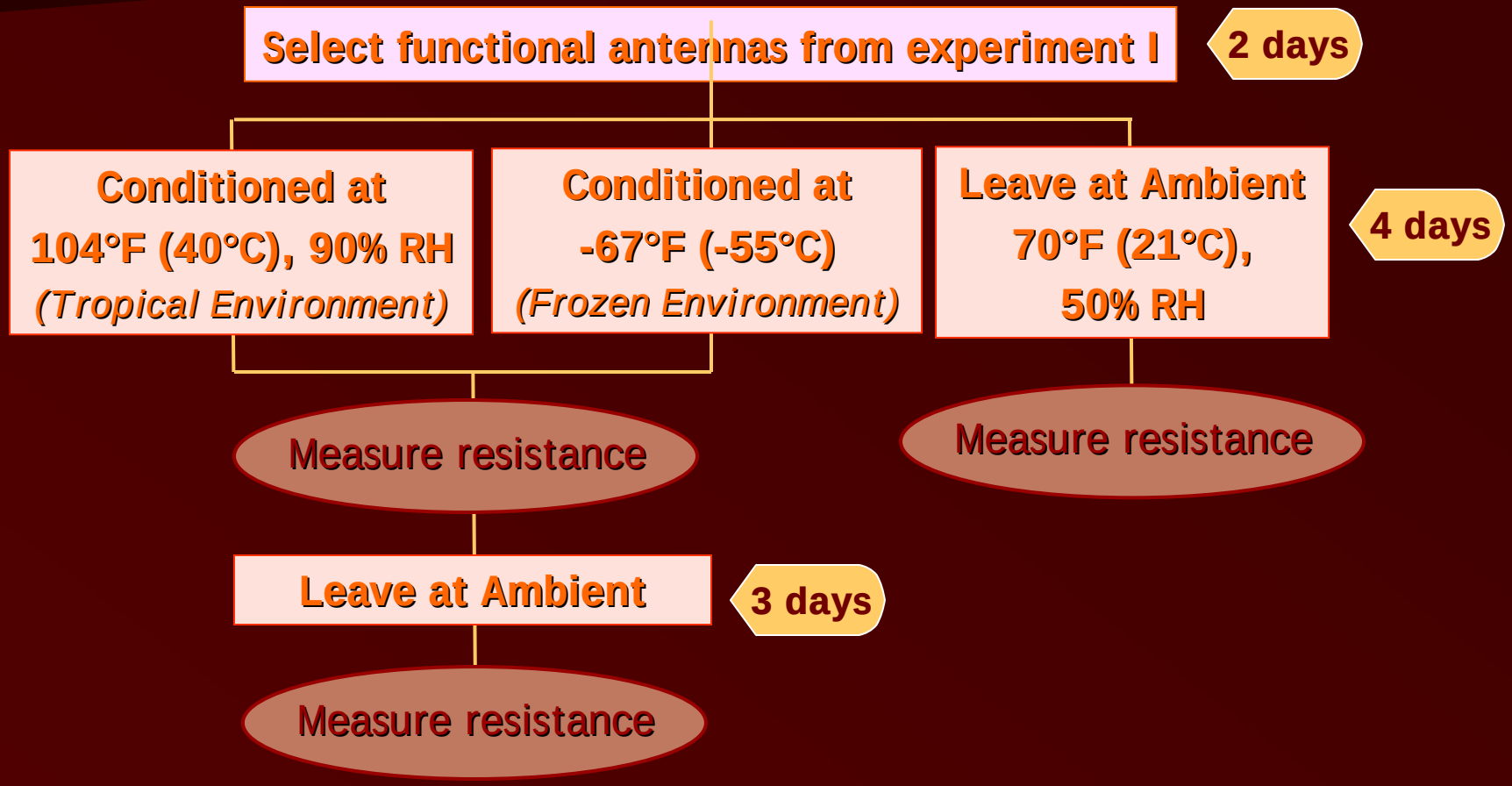
Experimentation I: Conductivity of the printed antenna

Conclusion:

- Although kraft and corrugated substrates gave lower conductivity compared to coated paper, their antennas were conductive suggesting that the substrates could be used for printed RFID
- Modification on physical properties of these substrates may help to improve printability, and allow them to provide better conductive antennas

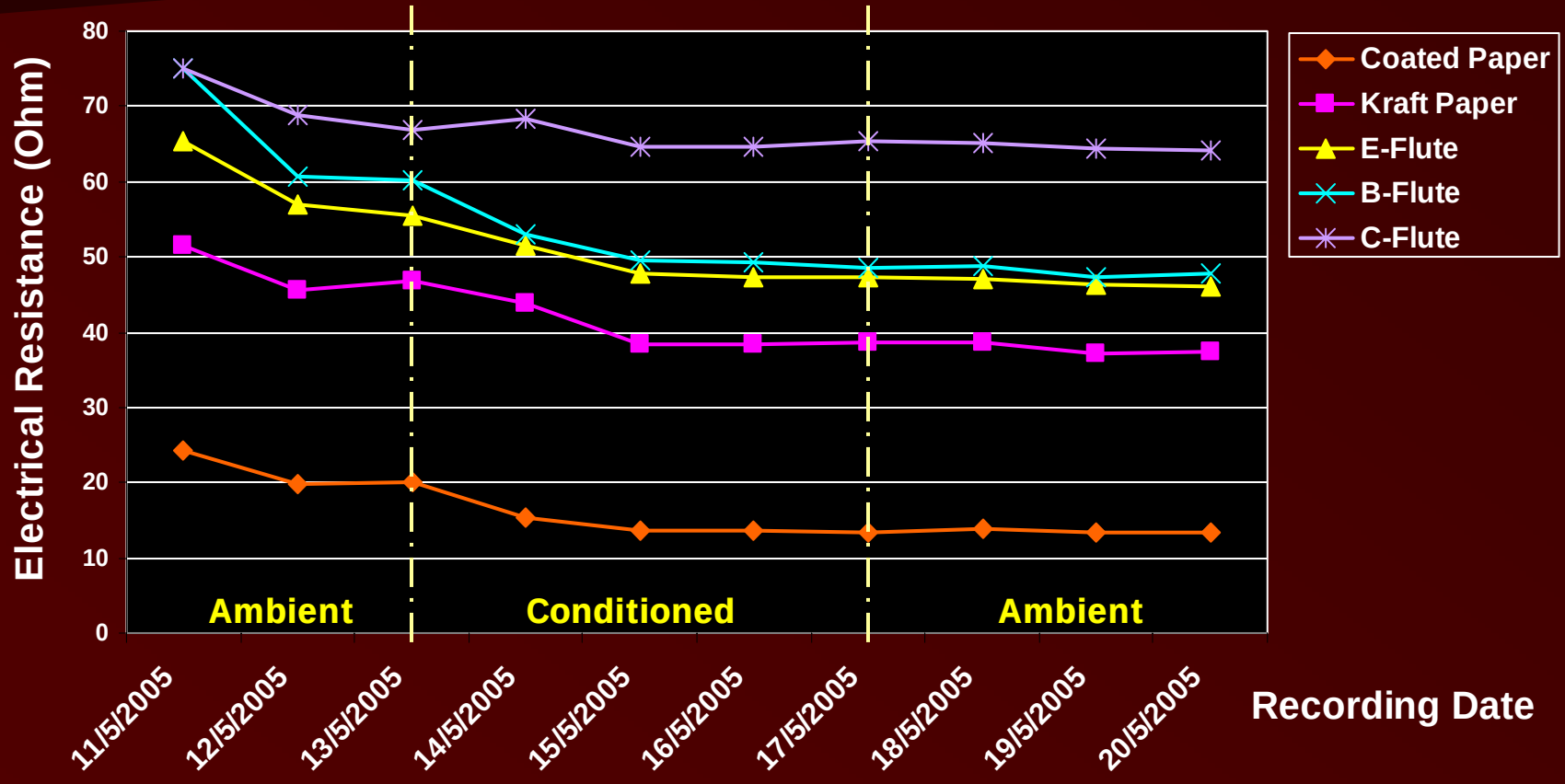
Experimentation II: Performance of the antennas in severe environments

Test Parameter: **Electrical Resistance (Ω or Ohm)**



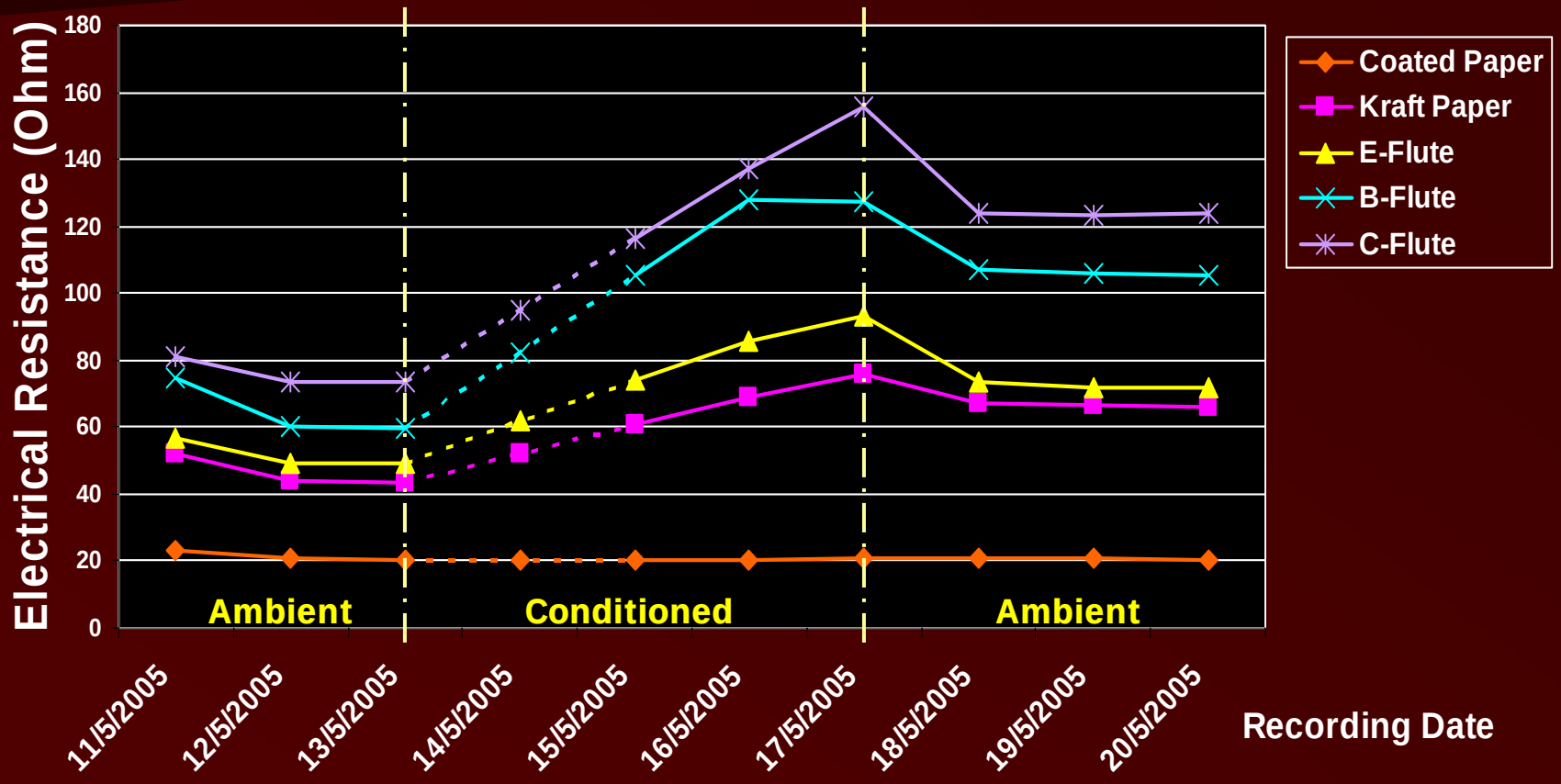
Test Result : Conditioning & Measurement

Tropical Environment (104 F, 90%RH)



Test Result : Conditioning & Measurement

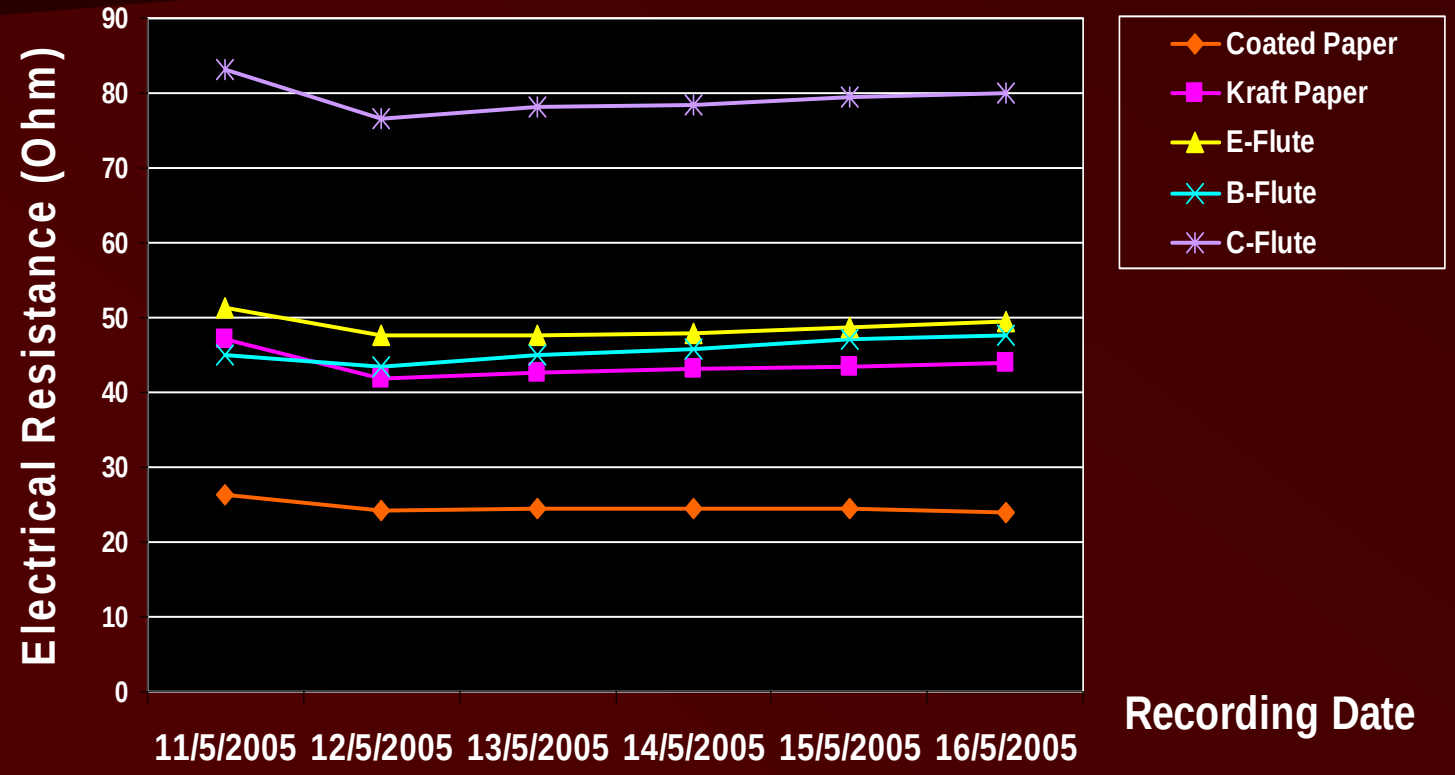
Frozen Environment (-56 F)



Experimentation II

Test Result : Conditioning & Measurement

Ambient Environment (-56 F)



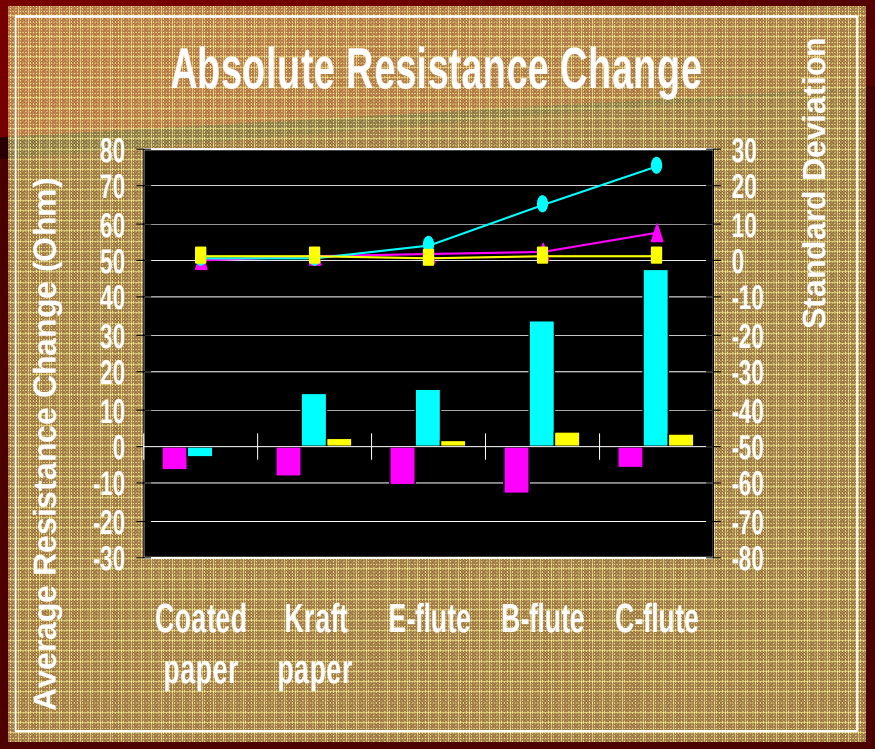
Experimentation II: Performance of the antennas in severe environments

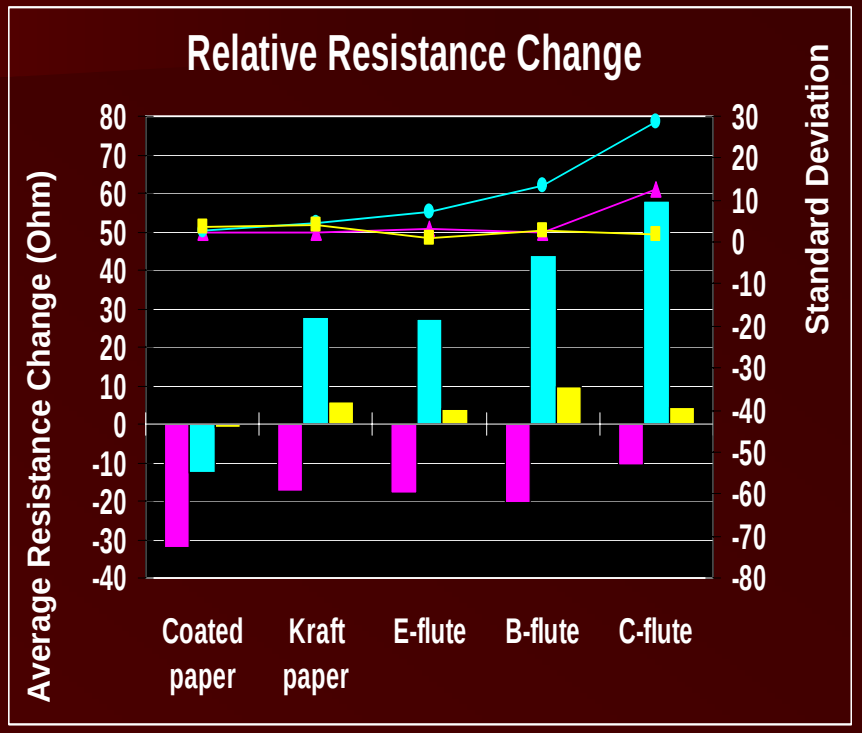
Discussion:

For all Substrates;

- Tropical Environment **improved conductivity of the antennas.**
- Frozen Environment **showed significant reduction in conductivity of the antennas.**
- Ambient Environment **had slight effect on conductivity of the antennas (no significant change).**

Test Result : Data Analysis





Tropical: Average
Frozen: Average
Ambeint: Average
Tropical: Std. Dev.
Frozen: Std. Dev.
Ambient: Std. Dev.

Minus values represent the decreases of resistance change. Plus values represent the increases of resistance change.

Experimentation II: Performance of the antennas in severe environments

Conclusion:

- The antennas on Kraft paper and corrugated substrates had much greater conductivity-change (in value) in all given environments, compared to coated paper (label substrate).
- However, the conductivity of those substrates showed smaller proportional changes, compared to coated paper.

Conclusion: Wrap-up

- Kraft paper and corrugated paperboard could be used for printing RFID antennas.
- Kraft paper gave more-conductive antennas than corrugated, suggesting that pre-printing may be an opportunity for printing antennas.
- Environmental changes have a significant impact on the antennas printed on kraft paper and corrugated.

Further Studies: The related topics

- Improvement of kraft paper and corrugate paperboard for printing RFID antennas applications using primers and surface-preparations
- Printing RFID antennas with microchips attached in line for packaging conversion
- The potential of using pre-printing process for printing RFID antennas on corrugated packaging, compared to post-printing process

Dedication: the Deepest of Appreciation

- Dr. Bruce Kahn, *my encouraging head-advisor*
- Mr. Daniel Clark, *my patient mentor*
- Prof. Deanna Jacobs, *my thoughtful advisor*
- Prof. Karen Proctor, *my helpful advisor*
- Dr. Daniel Goodwin, *my assisting advisor*
- Mr. Dan Lawrence, *a meaningful supporter*
- Mr. Michael Petersen, *a wonderful supporter*
- Mr. Chalermlarp Rungkamol, *my very supportive friend*

THANK YOU FOR YOUR ATTENTION !