Rectennas for energy harvesting of RF for feeding low power devices

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The energy harvesting is the process in which the energy from external sources is captured and stored to feed low power devices.
What is a Rectenna?

Receiving Antenna

Matching circuit → RF to DC Conversion (Rectifier) → Energy Storage

Rectenna

GSM-1800/4G

WLAN (2380-2450 MHz)

3G/UMTS-2100

RF-DC Rectifier

Compact Broadband High Gain Antenna

Internet of Things
What are the design challenges?

- Antenna
  - Shape
  - Size
  - Material
  - Polarization
  - Frequency

- Matching circuit
  - Filter
  - Quarter wave transformer

- Rectifying circuit
  - Type of diode
  - Number of stages
Any antenna designer must model a particular shape of the antenna and give the radiation parameters such as gain, impedance, VSWR, S-parameter, frequency range, polarization, so on.
Here, the design problem consists in finding a structure to match the antenna impedance and the rectifier impedance. The coils and capacitors must be printed on board circuits. We normally use filters to reject any harmonic because of the diodes.
Here, it is important to design a circuit with some stages to obtain more voltage, however, many of the capacitors or coils must be also printed on board.
Example 1

A textile rectenna for 800 MHz band obtain 14uw/m²

Energy harvesting system at GSM-900 MHZ, this system can obtain 2.9 volts by means of a rectangular patch antenna on a FR substrate and a 7-stage rectifier circuit.

This other system operates at 2.45 GHz. Its main novelty is a 40.1% of rectifying frequency.

A patch rectenna array of 4 rectangular elements at GSM-1800 MHz with a gain of 9.2dBi.

This other research reported a circular rectenna array of 6 elements at 915MHz for energy harvesting.

Example 5

This other research presented a rectenna array of 16 elements at 35.7GHz with a rectifying efficiency of 67%.

A microstrip patch rectenna arrays at 2.4 GHz with 100mV of DC output voltage:

<table>
<thead>
<tr>
<th>Type</th>
<th>Frequency</th>
<th>DC OUTPUT</th>
<th>Size</th>
<th>Rectifier</th>
<th>Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectangular textil patch</td>
<td>876 MHz</td>
<td>1.42 v</td>
<td>139mmx240mm</td>
<td>Built-in 1 stage doubler</td>
<td>Low gain</td>
</tr>
<tr>
<td>Rectangular patch</td>
<td>900 MHz</td>
<td>2.9 v</td>
<td>85mm x 106mm</td>
<td>Built-in 7 stages doubler</td>
<td>Low gain</td>
</tr>
<tr>
<td>Rectangular patch</td>
<td>2.45GHz</td>
<td>9.7v</td>
<td>Not provided</td>
<td>Non integrated</td>
<td>Low gain</td>
</tr>
<tr>
<td>Rectangular patch</td>
<td>5.8 GHz</td>
<td>9.8 v</td>
<td>Not provided</td>
<td>Non integrated</td>
<td>Low gain</td>
</tr>
<tr>
<td>4-element rectangular patch array</td>
<td>1.78GHz</td>
<td>Not provided</td>
<td>144 mm x 130 mm</td>
<td>Non integrated</td>
<td>Directive / Moderate gain</td>
</tr>
<tr>
<td>6-element rectangular patch antenna array</td>
<td>915MHz</td>
<td>Not provided</td>
<td>300 x 300 mm</td>
<td>Non integrated</td>
<td>Directive / Moderate gain</td>
</tr>
<tr>
<td>16-element rectangular patch antenna array</td>
<td>35.7GHz</td>
<td>3v</td>
<td>30mm x 30mm</td>
<td>Integrated</td>
<td>Directive / Moderate gain</td>
</tr>
<tr>
<td>4-element rectangular patch</td>
<td>2.4 GHz</td>
<td>100mV</td>
<td>120mm x 120mm</td>
<td>Non integrated</td>
<td>Directive / Moderate gain</td>
</tr>
</tbody>
</table>
Objective:
Design a rectenna array of wideband elements from 1GHz to 3GHz with 360° degrees of coverage.

Wideband example

- Vivaldi elements
- One stage rectifier circuit
- Circular array
FR4 Board with 1.27mm of thickness and permittivity of 4.3. The element impedance is 100 ohms.
Rectifier circuit

Wideband example

1 stage rectifier circuit with 4 Schottky diodes

ENER 2019. Curicó Chile, May 10, 2019
Wideband example

Rectenna Element

Rectifier circuit

<table>
<thead>
<tr>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
<th>g</th>
<th>h</th>
</tr>
</thead>
<tbody>
<tr>
<td>98mm</td>
<td>122mm</td>
<td>53.7mm</td>
<td>54.93mm</td>
<td>1.1mm</td>
<td>1.54mm</td>
</tr>
<tr>
<td>i</td>
<td>j</td>
<td>L1/L2</td>
<td>C1 to C4</td>
<td>C5 to C6</td>
<td>D1 /D2</td>
</tr>
<tr>
<td>4.5mm</td>
<td>1mm</td>
<td>22nh</td>
<td>0.1pf</td>
<td>82pf</td>
<td>HSMS2850</td>
</tr>
</tbody>
</table>
Wideband example

Circular Rectenna Array mounted in a 3D printed base

Rectenna array structure: a) top view and b) perspective view.
The rectifying efficiency was 39%.
Conclusions

• The energy harvesting by using rectennas is other alternative to feed low power devices.
• Some important issues are in current designs, however, this technology is still emerging and has potential applications for near future.
• Future works are mainly oriented to miniaturized the rectennas.
THANK YOU