Tronics RF-MEMS Switch: Status & Benefits for Active Antennas
Content

- Company overview
- Introduction to RF MEMS switches
- Tronics’ RF MEMS switch
- RF MEMS switches for Active Electronically Steerable Antennas
- Conclusions
Who is Tronics?

Tronics designs, manufactures and sells custom or standard MEMS products for high growth markets.

- **Life sciences**: Transducers and Proteomic MicroArrays
  - Diagnostic & therapeutics

- **Consumer**: Combo sensors
  - Activity monitoring, remote control

- **Industrial**: Sensors and actuators
  - Seismic oil exploitation

- **Aerospace & Security**: High performance gyro and accelero
  - Navigation & stabilization
Key facts & figures

- 92 employees including 55 engineers and scientists
- 2015 revenue: $12.5 M
- 15 years of R&D
- 25 active patent families
- >1,500,000 high performance devices produced
- Listed on Alternext Paris since February 2015
- 2 direct production sites, plus distributors in Japan, China, Israel and Turkey

Tronics (Dallas)
Tronics (Grenoble)
Advanced MEMS product developments

- Inertial Devices
  - Gyros
  - Accelerometers
  - Geophones
  - Arming Devices

- Optics
  - Gratings
  - Silicon Lenses
  - Mirrors
  - Optical Filters

- Microfluidics
  - Assays
  - DNA Chips
  - Diagnostic Chips
  - Micro-pumps

- Innovative Devices
  - Transducers
  - RF Circuits
  - Print Heads
  - µmechanic
Introduction to RF MEMS switches I

1990s: First publications (Hughes Research Lab, Rockwell Science, TI)

2001: more than 30 companies working on RF MEMS switches (including Motorola, AnalogDevices, Samsung, ST-microelectronics, Thales) and various research labs worldwide

Excellent RF performance, but major reliability issues hindered industrialization

2003: First products announced (Magfusion, Terravicta, Radant) but no success

A lot of companies stopped their activities

Since 2013: Several new products that seem to be successful (WiSpry, Cavendish Kinetics, Analog Devices)
Introduction to RF MEMS switches II

- MEMS = Micro devices, having movable parts, fabricated with processes similar to IC fabrication.

- RF MEMS = MEMS devices capable of reconfiguring the RF characteristics of a device.

- RF MEMS switches can be stand alone devices (e.g. SPST, SPDT or xPyT) or be used in RF Circuits (phase shifters, filters, ..)

- Typical configuration:

from K. Van Caekenberge “RF MEMS on the Radar”, IEEE microwave magazine October 2009
The Concept of TRONICS RF MEMS switch

- Developed in partnership with AIRBUS

Switch concept: Airbus

Fabrication technology, WLP& TSV: Tronics

- Capacitive, series switch
- Normally open
- Electrostatic actuation
General features of TRONICS RF MEMS switch

- Design adaptable from 2 GHz to 70 GHz
- Wide band response
- High power handling
- Low actuation voltage <24V
- Low power consumption
- Small and low weight
- Hermetic Wafer Level Package
- SMD compatible => Easy integration and reduced footprint on board
- ITAR-free solution
Example of SPDT switch configuration & integration

Example: SPDT

Assembly examples
wire bonding
SMD mounting
Example of typical performance SPDT 12 – 18GHz

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SPDT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency range (GHz)</td>
<td>12-18</td>
</tr>
<tr>
<td>Actuation voltage (V)</td>
<td>&lt;24</td>
</tr>
<tr>
<td>Switching speed (µs)</td>
<td>&lt;50</td>
</tr>
<tr>
<td>Insertion loss (dB)</td>
<td>1</td>
</tr>
<tr>
<td>Isolation (dB)</td>
<td>&gt;35</td>
</tr>
<tr>
<td>Matching (dB)</td>
<td>-15</td>
</tr>
<tr>
<td>Max. input power (dBm) (hot switching)</td>
<td>&gt;40</td>
</tr>
</tbody>
</table>

![Graph showing performance parameters vs frequency](image)
Preliminary Reliability Results

- First reliability tests passed without degradation of S-parameters, actuation voltage, and switching time:
  - **Switching cycles** > 60mio
  - **Thermal cycling**: 3 consecutive temperature cycles according to JEDEC J-STD-020 rev. C with 260°C peak temperature
  - **Exposure to humidity**: 1 h pressure cooker test
  - **Mechanical shock**: 5 consecutive shocks in all 6 axis 1500g for 0.5ms (MIL-STD-883J)
  - **Power handling (hot)** > 10W (unpackaged switch):

- **Full qualification in 2016**
Benefits of RF MEMS switches in AESA

- Low losses
- High power handling
- Low power consumption
- Integrability into RF circuits (phase shifters, filters)

Figure 2. An X-Band MEMS Electronically Steerable Antenna containing 25,000 MEMS switches with a 0.4m² aperture area.

J. Maciel et al, MEMS Electronically steerable antennas for fire control radars, IEEE radar conference 2007
RF MEMS in T/R module

Matching network

Polarization switch

Tunable filter or Switchable filter bank

Phase shifter

VGA

Matching network

Tunable filter or Switchable filter bank

Phase shifter

VGA
RF circuits for AESA using RF MEMS switches (examples)

- Phase shifter*

- T-line matching network

- Tunable filter*

- Switched filter bank **


# Required switch performance

<table>
<thead>
<tr>
<th></th>
<th>Switch for Filter bank</th>
<th>Polarization switch</th>
<th>Status Tronics RF MEMS</th>
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</thead>
<tbody>
<tr>
<td>Frequency (GHz)</td>
<td>5-18</td>
<td>5-18</td>
<td>☺</td>
</tr>
<tr>
<td>Switch configuration</td>
<td>&gt;SP4T</td>
<td>SPDT, SP4T</td>
<td>☹</td>
</tr>
<tr>
<td>Insertion loss (dB)</td>
<td>&lt;0.3</td>
<td>&lt;0.3</td>
<td>☹</td>
</tr>
<tr>
<td>Isolation (dB)</td>
<td>&gt;30</td>
<td>&gt;20</td>
<td>☺</td>
</tr>
<tr>
<td>Max input power (W)</td>
<td>1</td>
<td>&gt;10 (peak)</td>
<td>☹</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;2.5 (mean)</td>
<td></td>
</tr>
<tr>
<td>Switching mode</td>
<td></td>
<td>cold</td>
<td>☺</td>
</tr>
<tr>
<td>Switching speed (µs)</td>
<td></td>
<td>50</td>
<td>☹</td>
</tr>
<tr>
<td>Switching cycles</td>
<td></td>
<td>&gt; 8x10^7</td>
<td>☺</td>
</tr>
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Source: Private communications R. Rieger, Airbus Defence & Space
Conclusion

- The combination of Tronics’ MEMS know how with the switch concept of Airbus allows the fabrication of RF switches
  - Wide band response
  - High power handling
  - Easy integration and reduced footprint due to Wafer level
  - Ultra-low power consumption
  - Small and low weight

- First demonstrators show very good RF performance and reliability

- Active electronically steerable antennas are an interesting application for RF MEMS

- Tronics’ goal is to set up an open technology platform for microwave and millimeterwave switches and circuits
Thank you!

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