Reconfigurable Circuitry as an Enabler for Real-Time Adaptive Spectrum Usage

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Reconfigurable Circuits Enabling Iterative Spectrum Policy

- Iterative (moving from rigid to real-time adaptive) spectrum policy could be limited by rigid circuitry.
- Example due to lack of circuit reconfigurability:
  - S-band military radar loses range when changing in frequency to avoid wireless communication.
  - 24 GHz 5G network must turn off to avoid passive sensors during operation.
- Potential impact of reconfigurable circuitry in these scenarios:
  - S-band radar reconfigures its circuitry within a millisecond after frequency changes to maintain detection range.
  - 24 GHz 5G network redistributes its spatial/spectral usage through an Artificially Intelligent Power Amplifier Array (AIPAA) to maintain needed transmission range while avoiding interference.
Example 1: Fast Radar Optimizations

- Intelligently controlled power-amplifier reconfigurable impedance tuner re-maximizes transmitter output power (and range) upon changes in frequency.

- Faster impedance tuners can be made out of electrically actuated devices and can reconfigure completely in under 600 µs.
Example 2: Artificially Intelligent Power Amplifier Array

- 5G mm-wave transmitter application is shown, but can also apply to radar.
- Reconfigurable impedance tuner between each power amplifier and transmitter antenna.
- Can optimize for gain or power-added efficiency (PAE) while meeting spatial-spectral mask requirements from the broker.
- Circuit tuning impacts transmissions*.

Example 3: Spatial-Spectral Broker*

5G to Radiometer Interference Assessment Mechanisms:
- On-board 5G element power and spectrum measurements using 5G transmitter controller
- Radiometers also assess harmful interference and report to Broker, which reports to 5G Transmitter Controller.

On-Board Element Power and Spectrum Measurements

Array Element Excitations for Beam Forming
Array Element PAs with Reconfigurable mm-Wave Matching Circuits

Radiometer 1
Radiometer 2
Radiometer N

5G Transmitter Controller

Data Requested

<table>
<thead>
<tr>
<th>Data Requested</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date / Time</td>
<td>(24 hour time), start and stop time</td>
</tr>
<tr>
<td>Latitude</td>
<td>decimal degrees</td>
</tr>
<tr>
<td>Longitude</td>
<td>decimal degrees</td>
</tr>
<tr>
<td>Altitude</td>
<td>meters</td>
</tr>
<tr>
<td>Center Frequency</td>
<td>Hz</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>Hz</td>
</tr>
<tr>
<td>Azimuth</td>
<td>degrees</td>
</tr>
<tr>
<td>Elevation</td>
<td>degrees</td>
</tr>
<tr>
<td>Transmitter Power</td>
<td>dBm</td>
</tr>
<tr>
<td>Receiver Power Tolerance</td>
<td>dBm</td>
</tr>
<tr>
<td>Antenna Gain</td>
<td>dB</td>
</tr>
<tr>
<td>Time Interval Request</td>
<td>seconds</td>
</tr>
<tr>
<td>Interference Frequencies</td>
<td>Hz</td>
</tr>
<tr>
<td>Interference Levels</td>
<td>dBm</td>
</tr>
</tbody>
</table>

A manifold request is submitted by each spectrum user.

The broker uses a culling process to compare manifold requests.

A spatial-spectral mask is given to the active transmitter for circuit/array optimization.

Conclusions

• Iterative spectrum usage must progress from completely rigid spectrum use to as close to real-time assignment as possible (governed by the scenario).
• Adaptive spectrum usage is enabled or limited by circuit reconfigurability.
• Emerging circuit reconfiguration capabilities will enable adaptive use of two critical spectrum areas:
  – S-band radar sharing with 5G: High-power, fast tunable reconfigurable circuits and Artificially Intelligent Power Amplifier Array (for radar transmitters)
  – Passive weather sensing with 24 GHz 5G: Spectral broker and AIPAA