Superconductor Microelectronics and Security for Software Defined Radio

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Overview (I)

- Software Defined Radio (SDR) is a widely recognized technology promoted by SDR Forum
- Digital RF™ is an unique technology using superconductor microelectronics to provide the dramatic improvements in performance necessary to realize full SDR potential
- Topics for discussion
  - The Wireless Opportunity
  - HYPRES Digital RF Technology
  - System Security

Overview (II) Wireless System Technologies

- **Software Defined Radio (SDR)**
  - Signal processing takes place in digital rather than analog form, using programmable computing elements, providing operational flexibility
- **Digital RF™**
  - Hypres unique superconductor technology that provides high-performance digital processing capability and incorporates innovative circuit elements to:
    - Fully enable SDR, to the level of pure Software Radio
    - Operate at clock rates over 100 GHz
    - Reduce cost with increased receiver sensitivity and precompensation for power amplifier characteristics
    - Facilitate incremental introduction of novel system architectures, features, and services
- **Security**
  - Assurance that the system is performing as desired
  - A perspective involving multiple technologies

The Wireless Opportunity

The Wireless Opportunity (I)

- **Two parallel and interacting trends are changing the world marketplace**
- **One trend is *DIGITAL DATA* as the basis for information exchange and interaction, replacing letters, phone calls, even face-to-face meetings**
- **Data traffic exceeded voice on the PSTN for the first time in the year 2000**
- **PCs, Mobile Phones, PDAs, and other information appliances have become ubiquitous**

The Wireless Opportunity (II)

- **The other trend is *MOBILITY***
- **Wireless technology permits individuals to remain connected, with their own personal infrastructure, wherever they are**
- **A substantial revenue stream has emerged from user payment for services that provide Personal Capability Enhancement (PCE)**

Digital Data *and* Mobility *are important aspects of our evolving economy and society, providing* PCE

HYPRES Digital RF™ Technology

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HYPRES Digital RF Technology

- **Based on Rapid Single Flux Quantum (RSFQ) Logic Family of Superconductor Circuits**
  - **Marshal individual quanta of magnetic flux ("fluxons") to serve as binary digits**
    - **Logic stream and clock stream**
    - **In logic stream, for each fluxon in the clock stream, presence of a fluxon = 1, absence = 0**
  - **Substantially outperforms and semiconductor logic implementation**
  - **No power loss in superconductor logic circuits**
    - **$i^2r = 0$ when $r = 0$**

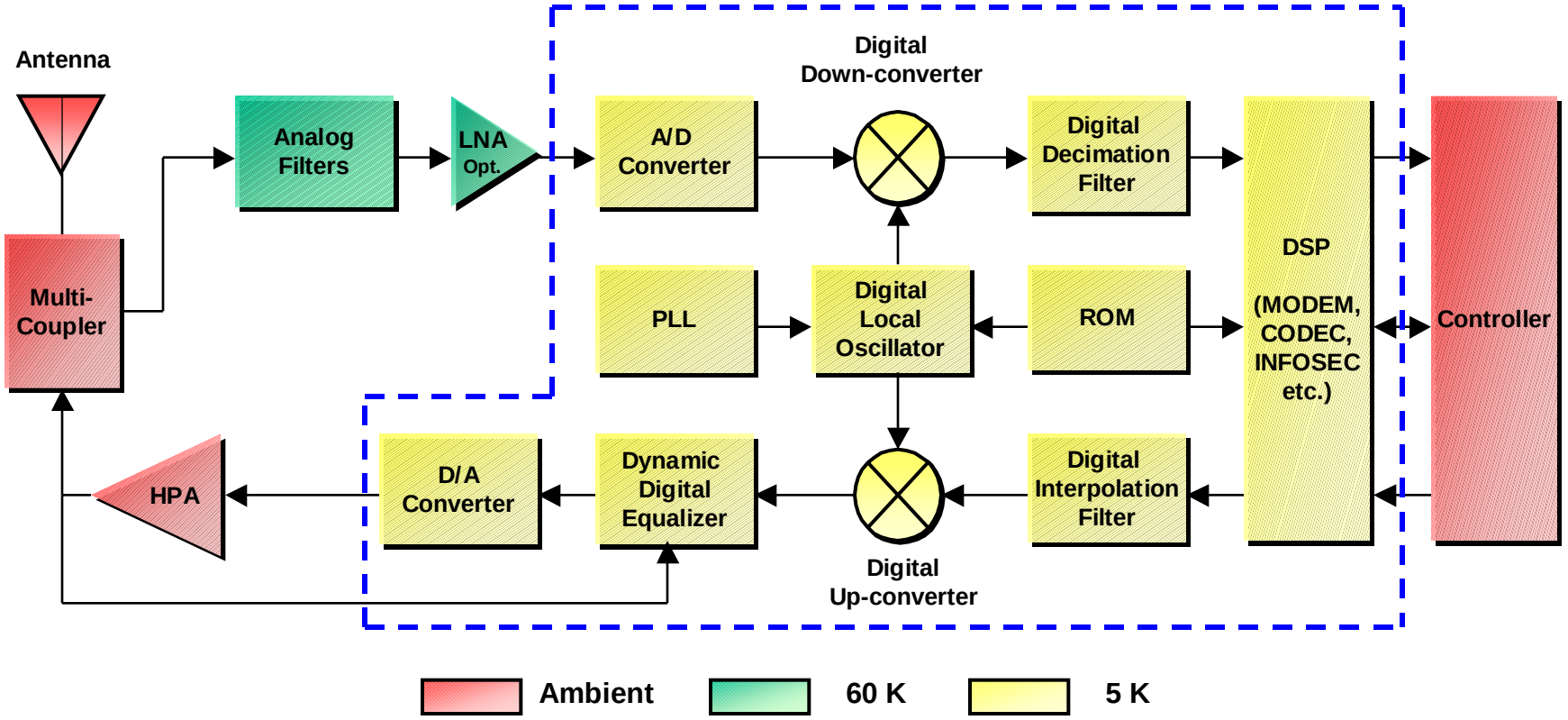
Digital RF Characteristics (I)

- **Wideband high-fidelity receive DIRECT digitization**
  - **14-24 effective (true) bits, 100 – 160 dB Spur Free Dynamic Range, <100KHz to >2GHz bandwidth**
  - **Dynamic trade-off of sample rate and sample resolution**
  - **Digitize entire band, select desired channels digitally**
  - **Very sensitive front end, ~0K noise temperature, sensitivity -140 to -180 dBm, better than 10^{-15} bit error rate**

Digital RF Characteristics (II)

- **Spectrally-pure transmission characteristics**
  - **Inherently perfect Digital to Analog conversion**
  - **Clock speeds > 100GHz**
  - **Combine transmitted signals digitally to form composite**
  - **Near Real Time RF Digital Linearization Multi-Carrier Power Amplifier (MCPA)**
  - **Ultra-linear & Very High Efficiency HPA performance realized with lower-performance PA**
  - **Spectrally pure carriers derived from sub pico-second accurate multi-GHZ clocks**
  - **Extended digital processing capability**
  - **Tera-Ops DSP performance**
  - **Pico-second RAM/ROM**

Digital RF Transceiver



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Digital RF Benefits (PCS example)

- **Lower cost per base station**
  - Fewer PAs
  - Lower cost PAs
- **Fewer base stations**
  - High receiver sensitivity permits wider spacing, lower noise floor
- **Lower Operating and Maintenance cost**
  - Less power consumption
  - Fewer spans
- **Better revenues**
  - More effective capacity
  - Fewer dropped calls
  - Customer satisfaction reduces churn
- **Improved service quality**
  - Resolve multipath
  - Read through fading

Corresponding benefits, unique to Digital RF, arise in Civil and Military Applications

System Security

System Security

- Security is that system attribute that ensures the system accurately delivers content only to intended recipients with no interception or disruption
- Performance levels achievable only with Digital RF enable security mechanisms commensurate with needs arising from current events
- Security considerations include
  - Normal Operations
  - Infrastructure Reconfiguration (Download)
  - Spectrum Management
  - Alternate Operations

Digital RF – Normal Operations Security

- **Control Access**
  - Digital RF and SDR capabilities enable priority structure, controlled access denial for load shedding, shut down rogue terminals
- **Ensure Delivery**
  - Receiver sensitivity and transmit signal quality unique to Digital RF enable lower power operation, high levels of QoS, better link reliability, dynamic antenna operation
- **Deny Interception**
  - Digital RF provides compute power needed for robust encryption, reduced emitted power, geolocation controlled zone of reception

Digital RF –Reconfiguration Security

- **Network Oriented Base Station**
  - With Digital RF performance BS can assume functions formerly in core network – support multiple services, access multiple networks, interact with other BS, optimize performance over a group of BS
- **Software Download for BS**
  - SDR enables download of bug fixes, new functions, reallocate channels in real time, insert whole new services
- **Software Download for Terminals**
  - Provide configuration management services for terminals, update terminal SW, change operating modes, provide extra bandwidth during download

Digital RF – Spectrum Mgmt. Security

- **Dynamic Spectrum Management**
  - Only Digital RF enables precision control of transmission quality to make spectrum sharing practical
  - Vastly improves the effective capacity of RF spectrum
  - Many services can safely and efficiently share pools of spectrum
- **Spectrum Monitoring**
  - Digital RF unprecedented sensitivity enables infrastructure to serve as a reconnaissance platform, monitor wide blocks of spectrum, identify non-conforming terminals, and record special signals of interest
- **Emitter Location**
  - Digital RF data accuracy enables location of emitters of interest through triangulation and delta TOA

Digital RF – Security for Alternate Operations

- **Priority Access**
  - **Digital RF provides a unique capability to alter operations in a secure way to support emergency needs**
    - **Traffic channel allocation on the basis of priority**
    - **Secure dynamic restructuring of channel allocations**
- **Reconfigure BS to support emergency Services**
  - **Digital RF provides exceptional BS capacity to support additional operational capability**
    - **Situation awareness**
    - **Geolocation**
    - **Command and control**
    - **Secure voice communication**
    - **Data transfer**
- **Repeater station bridge between protocols**
    - **Diverse organizations, arriving on-site with incompatible communications capability, can interoperate**

Conclusions

- As digital information flow replaces analog voice, and moves on to support PCE applications, users expect connectivity anywhere
- Demand for infrastructure performance and system security is increasing
- SDR technology provides system flexibility and responsiveness
- HYPRES Superconductor Digital RF technology uniquely enables true/pure SDR, enhances system performance, and facilitates new approaches to system architecture and security

Supplementary Slides

Base Station Evolution

- Originally a one-way service (“Calling all cars!”)
- Then a two-way half-duplex RF link
  - Awkward, because some mechanism (“over”) was needed to turn the circuit around
- Cellular wireless service brought full-duplex
  - An extensive PCS infrastructure has been built, originally analog, now digital
- Digital RF implementations of SDR for base stations benefit Commercial, Civil, & Military radio users
- Only Digital RF combines better performance for existing services and performance levels needed for SDR and support for delivery of next-generation applications for PCE tailored to individuals

Commercial Space

- Data traffic exceeded voice on the PSTN for the first time in the year 2000
- Wireless technology permits individuals to operate with their own personal infrastructure even when they are away from their office or home, providing tailored PCE
- Many services are all digital, such as dispatch with data terminals in vehicles
- Use of these services leads to a growing demand for spectrum bandwidth

Civil Space

- **A number of Federal, State and Local agencies operate their own networks**
  - **Use a single high-powered base station - “trunking”**
  - **Large numbers of users typically listen to each others’ traffic**
- **Now cellular PCS & low-cost handheld terminals are available**
  - **cost differential for maintaining separate radio systems for civil applications is making their need less compelling**

Military Space

- Uses many incompatible radios that severely inhibit inter-service communications
- Joint Tactical Radio Systems (JTRS) Joint Program Office (JPO)
  - Use SDR to overcome these incompatibilities
- Unique requirements from civil & commercial
  - Networks need a flexible infrastructure
    - Net participants come and go as the battle evolves
  - Employ high levels of encryption
    - Deny access to information content (COMSEC)
    - Enhance transmission security (TRANSEC) to deter traffic analysis