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Finding a clear path to a communications channel…

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From the session Introductory Statement:

- The world forever changed when the Aloha network matured in Ethernet. Through the years we have seen Ethernet be applied to local networks, metro networks, WiFi, WiMAX and now we are seeing a new phase where self organizing devices can cross spectrum to provide the way to find a clear path and maintain communication. This represents a great change for a series of applications that previously were too hard to implement.

The Cisco Projection…

- 92% CAGR of *mobile* data from 2010-2015
  - to 6.3 million Terabytes per month
  - ~40% of mobile data usage occurs in the home
- This will place immense pressure on operators to:
  - offload their mobile networks
  - Implement dual mode devices

- *TV-White Spaces (TV-WS) spectrum access offers a high data rate alternative solution!*

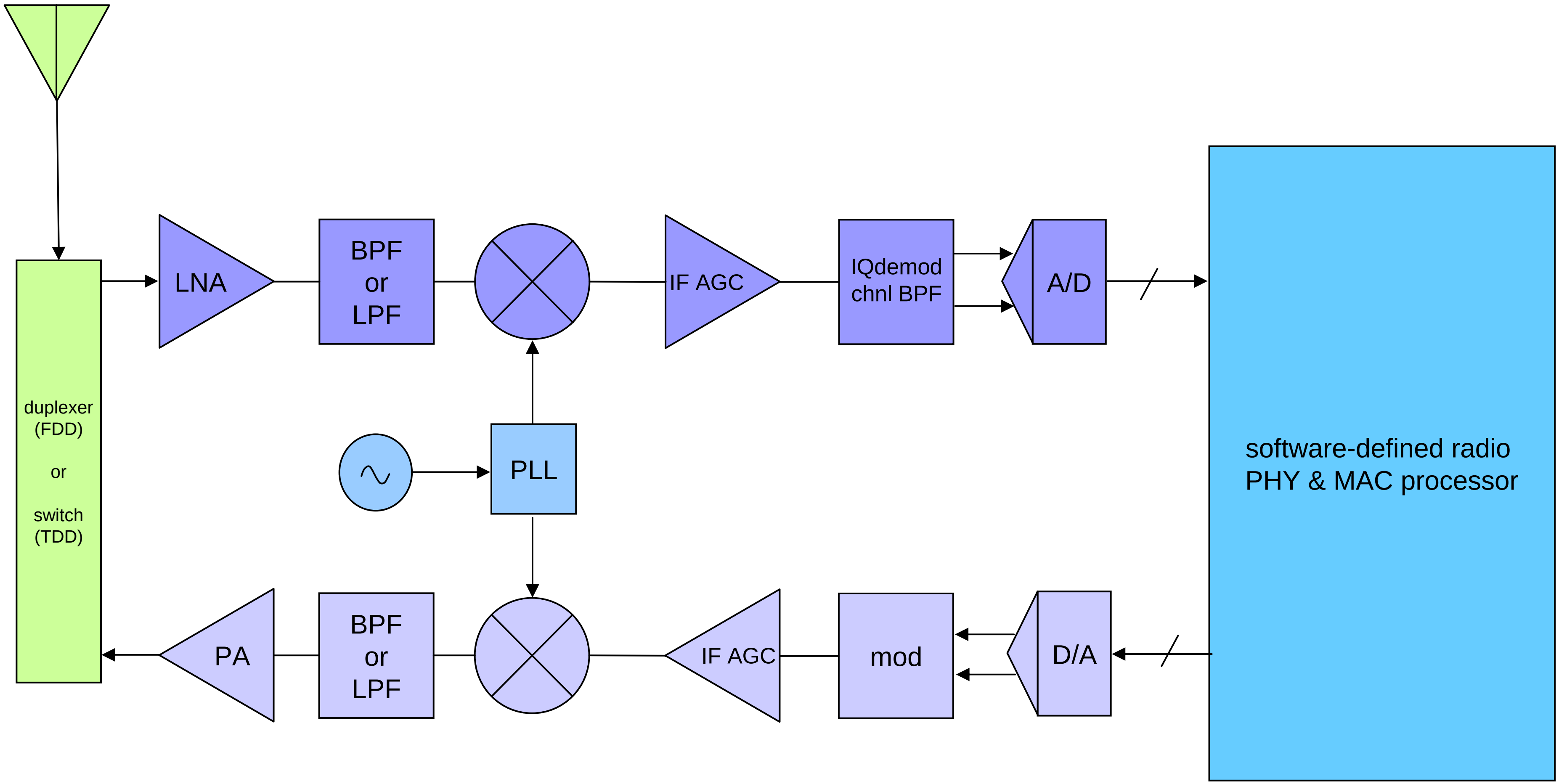
https://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html

The Issue…

Getting "devices to cross spectrum while maintaining existing communications"

- We need
  - regulatory authorities to institute regulations allowing for flexible wireless communications systems
  - Devices that can utilize channels as they become available
  - Devices that can sense the presence of RF carriers to avoid on-air collisions, and coexist with legacy infrastructure
    - CSMA/CD (*carrier sense, multiple access, collision detection)* technique first developed for use in the Aloha system
    - later employed by Robert Metcalf in the wired Ethernet standard
  - Hardware that can meet the new requirements for the TV-WS environment, react to the presence of legacy signals and 'adapt' to operate on a new, clear channel without a-priori assignment.

Generic Radio Platform



What does providing this capability for TV-WS entail regarding the key device characteristics?

- The RF front end would need:
  - Channel tune-ability and selectivity, over broad frequency and dynamic range.
  - Wide band, low noise performance
    - -114 dBm (far below the current -80 dBm TV tuner standard) ,
  - High linearity, to assure this selectivity can be maintained in the presence of high level adjacent channel signals
- The baseband processing engine must:
  - Support the required tuner agility for ‘location aware’ channel sensing and self-organizing networks
  - Provide control for power back-off, to minimize un-necessary emissions in compliance with FCC requirements
  - Have the flexibility to accept algorithm updates as required, to keep pace both with standards changes and evolutionary system performance upgrades.

Tuning Agility

- Low & zero-IF CMOS tuners satisfy the bulk of today's TD, FD, CD and CSMA/CD system applications
- In self organizing networks (SON)
  - nodes may take on the role of a master providing the channel assignments
  - the time to settle-in on a new channel may become a critical performance parameter
  - traditional Phase lock loop measures of bandwidth, phase noise performance, and settling time may come into consideration

Broadband, Low Noise Performance

- CMOS IC-TV tuners using a single wide-band RF Low Noise Amplifier (LNA) are becoming mainstream
  - Sufficient bandwidth & noise performance to detect signals down to -80 dBm
  - Tuners completely support analog and digital modulation formats.
- A TV-WS device must:
  - Have carrier sense capability to -114 dBm using a 0 dBi antenna, per the FCC
  - This level of performance likely precludes use of a single wide-band LNA
    - insufficient noise figures attainable from current wide band CMOS LNA's
- A TV-WS front end will likely utilize 3 (or more) band-switched, segment-optimized LNA's
  - Coverage for the full Channel 2-69 spectrum allocated
  - Respective LNA switched in depending on which channel needs to be sensed
  - Configuration typical of the high volume multi-band cellular handset market
  - Can be supplanted as CMOS or SiGe wide band device noise figures advance

Selectivity and Linearity

- On the Receive side…
  - The selectivity indicates the ability to effectively receive a low level channel, without interference from an adjacent channel signal. This can also be described as adjacent channel blocking.
  - Linearity provides a measure of how well the RF hardware faithfully reproduces the envelope and phase information being conveyed. Analog, digital HD, and Quadrature-Amplitude Modulation (QAM) technologies are increasingly dependent on signal fidelity, so linearity is critical to ensure reception of weak signals in the presence of much higher signals (say from a nearby transmitter) which can cause device operation in regions of non-linearity- i.e., consider the case of audio distortion from running the volume too high on a cheap stereo!

Transmit Linearity, Phase Noise, and Power Control

- The considerations are basically similar to the case of the receiver, however they need to be thought of from the system perspective.
  - Transmit nonlinearity can result in greater inter-modulation, causing energy to spill over into the guard bands between channels, or the channels themselves. This desensitizes nearby receivers operating in these adjacent bands.
  - Good transmit power control is necessary to maintain the minimum power needed to maintain the link data rate, and that is it- excess power can affect other neighboring devices operating in the selected band:
    - Remote controls for cranes
    - Wireless microphones
    - Broadcast TV stations
  - Sufficiently low phase noise is required to assure that the modulation constellation points are discernable from each other, so that there are few bit errors in receipt of a transmission.

Processing Engine

- Multi-mode devices capable of supporting TV-WS should have the following characteristics:
  - Multiple multi-threaded cores with high-performance vector DSPs, to support baseband processing for 4G UE data rates and multi-mode operation
  - An ARM processor core to support legacy protocol stacks and ease porting effort
  - Various peripherals to simplify system / device implementations
  - A Power-efficient design, which should contain embedded power management to support mobile device applications

- The platform should be self contained and fully programmable with support for:
  - C programming language
  - Integrated Development Environment
    - Complier
    - Simulator
    - Debugger & Board Manager

Some Representative Examples…

Sandbridge
Programmable Basebands

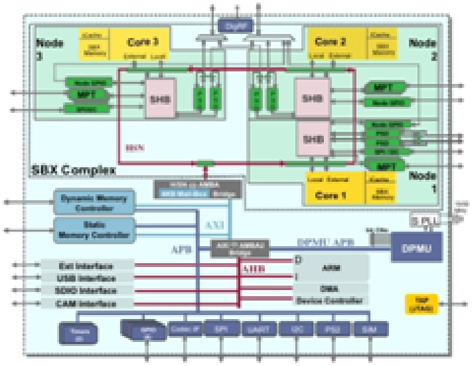
Founded 2001

First Demo Product

- SB3011- 2006

First Production Product

- SB3500 - 2009



BitWave
Programmable RFICs

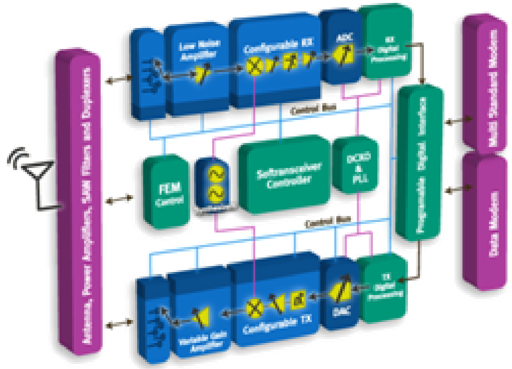
Founded 2003

First Demo Product

- BW1101 – 2007

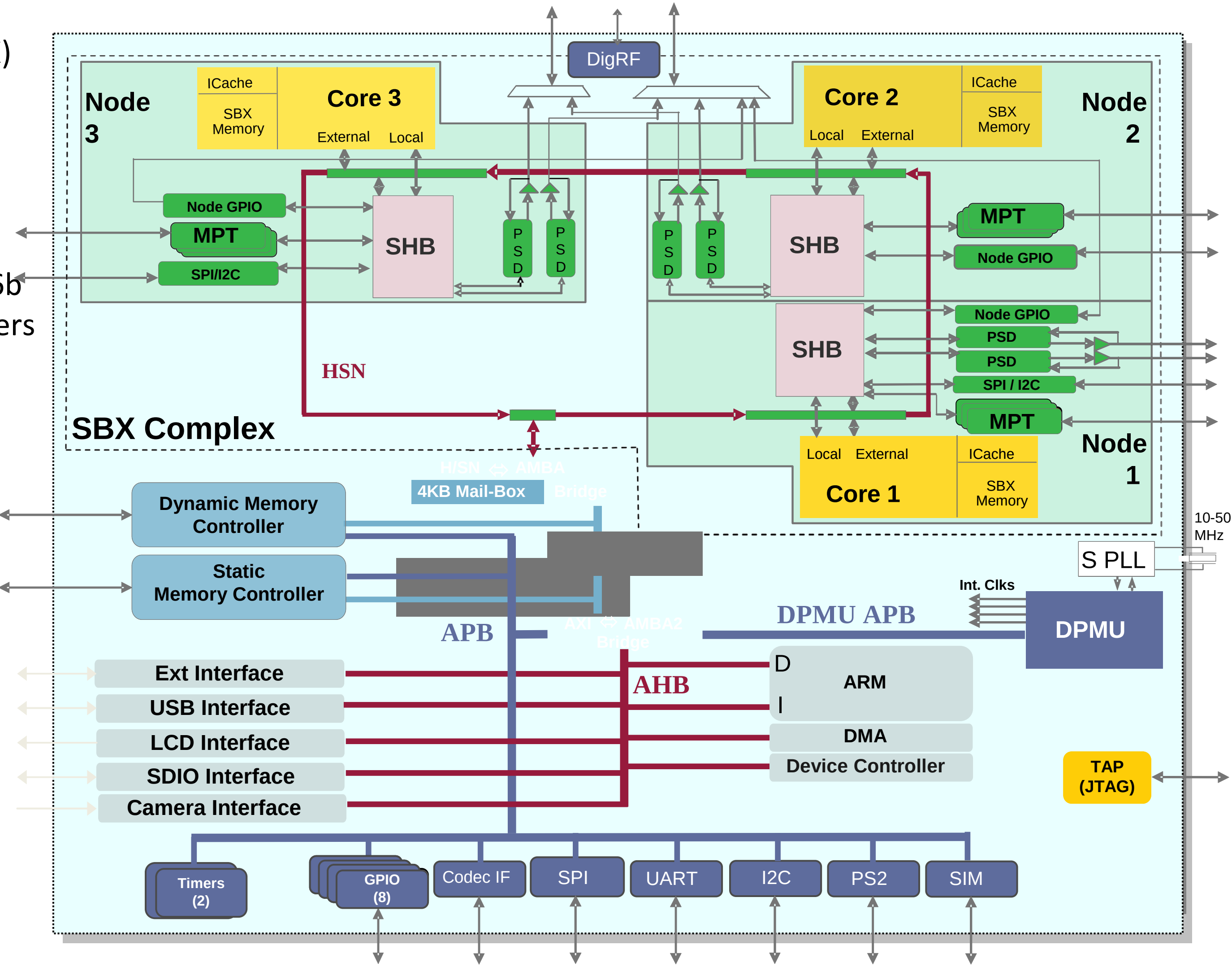
First Production Product

- BW1102 - 2009

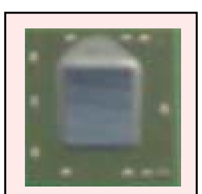


Optimum Semiconductor SB3500 Baseband Engine

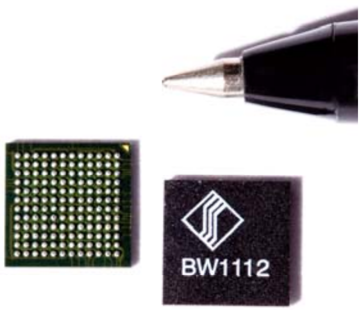
- 3 Sandblaster Extended (SBX) 2.0 DSP Architecture Cores:
  - 600MHz
  - 4-way threaded
  - 32KB I-cache
  - 256KB D-memory
  - Wide Vector Unit – 256b
    - 16x 16b Multipliers
    - 9600 MMAC/s
- HSN interconnect
  - point-to-point ring
  - 2.4GBs/link
- ARM926EJ-S
  - 300MHz
  - 16KB/16KB cache
  - 32KB/16KB TCM
- 65nm LP
- Production – 4Q09

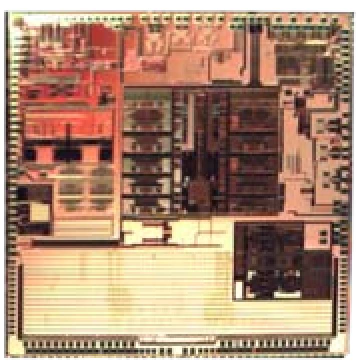


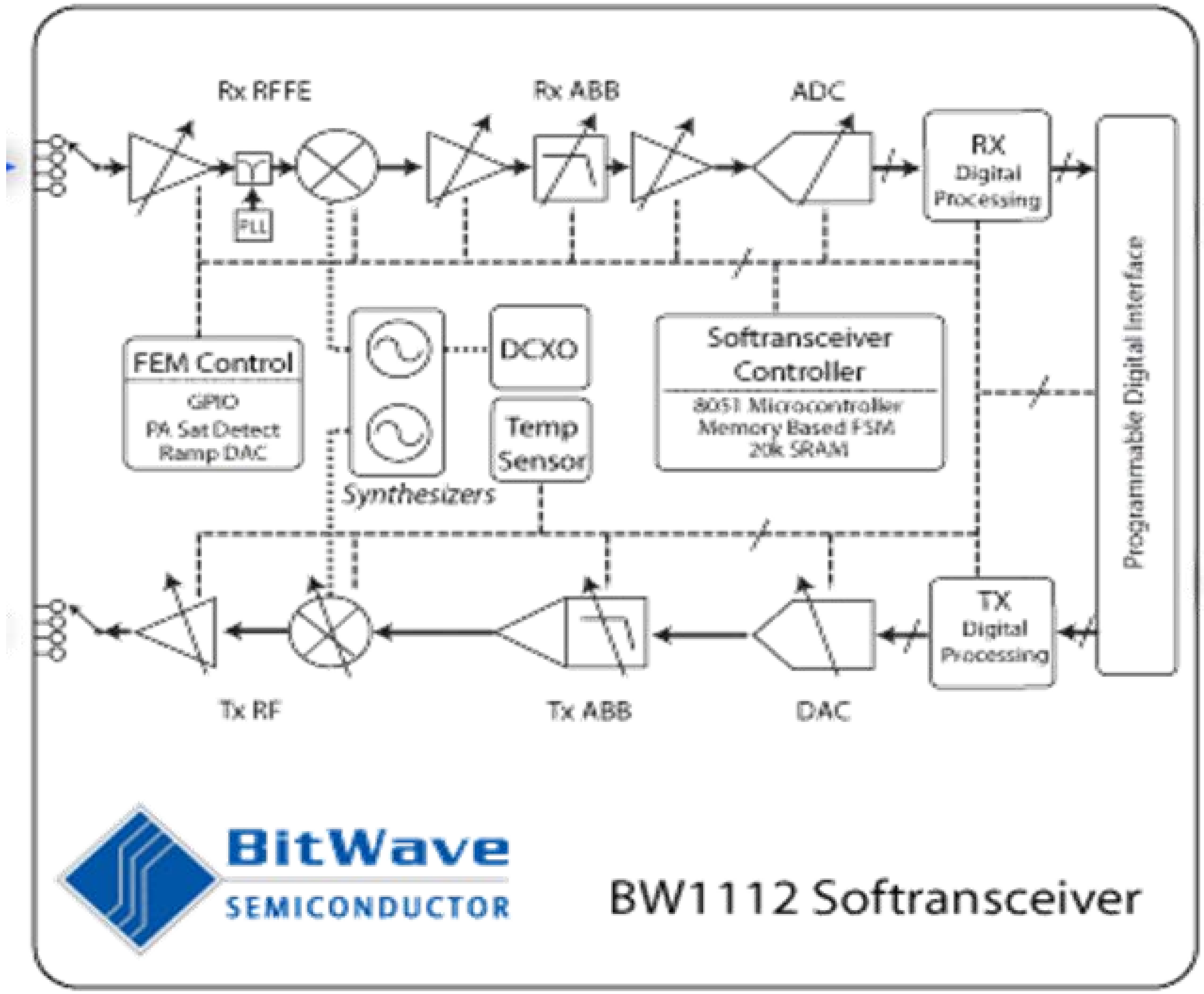
SB3500 device
13mm x 13 mm



BitWave BW1112 Softransceiver







Conclusions

- While TV-WS presents some implementation challenges, all the basic technologies exist, can be borrowed, & brought to bear:
  - High performance RF front end components / integration
  - Reconfigurable Baseband proven/production/available
  - Reconfigurable RF/IF demonstrated and becoming mainstream
- A key driver for growth will likely be implementation of multi-standard devices capable of diverting mobile network traffic to TV-WS, alleviating capacity limitations.
- Reconfigurable Communications Systems have been implemented, demonstrating viability of this approach to the ensuing capacity problem.
  - WiFi, LTE, WiMax, GSM/GPRS, ATSC (available, proven)
  - Can "hop" from band to band
  - Can switch air interface standard, supporting multi-mode operation
  - Easily support mandated carrier sense / collision avoidance protocols