Satellite Digital Audio Radio Service (SDARS)
System Architecture and Receiver Review

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Satellite Digital Audio Radio Service (SDARS)
SDARS System Requirements

Key System Level Receiver Requirements

Greater than 99.5% system availability. Auto industry certification (comparable to MIL standards) is necessary for all receivers.

Up to 128 channels of audio with a mix of CD-quality music channels and high quality talk channels (about 60/40).

Program Descriptive Text and Core Data transmitted along with each channel provide display provide up to 64 long names and 64 short names at the receiver.

Access security control for on-the-air activation, deactivation, clone elimination, tiered service protected by encryption (individually addressable to each end user unit).

Low delay for power up and tuning – typical tracking time to acquire signal is 50 milliseconds. Tracking acquisition 200 milliseconds, cluster sync acquisition 350 milliseconds additionally.

Video streaming capability - demonstrated. By proper formatting, it is possible to have a combination of audio and video streams.
Security Elements

To ensure that programs are accessible only to paid customers – security elements are built into the system.

Operational System (network part)

Manufacturing Control Database (linked to service provider database)

Manufacturing Customization (end user unit) Receiver

Transaction Workstation

LAN

Internet

LAN

Receiver

Manufacturing Workstation

Security Database (service provider)
SDARS System Impairments

• Specific 3-stream system reception design challenges were met by the receiver to overcome key impairments
  – **High system availability**
    • In order to achieve very high system availability, diversity in four domains (frequency, time, space, modulation) is used in addition to FEC and interleaving
  – **Doppler shift**
    • Elliptic, inclined geosynchronous orbit produces a large Doppler shift in the satellite signal. The receiver can compensate for at least 24 kHz for combined uplink and downlink Doppler shift. Also, due to the orbit, received signal strength and direction vary by time of day.
  – **Frequency offset**
    • High volume manufacturing requires low cost components. The system frequency reference has a tolerance of ± 15 ppm producing a frequency offset of up to 35 kHz for both satellite and terrestrial signals for which the receiver compensates.
SDARS System Diversity

In order to achieve very high system availability, diversity in four domains (Modulation, Frequency, Space, Time) is used in addition to FEC and interleaving.

Modulation Diversity
TDM for Satellite path – provides highly reliable satellite link
COFDM for Terrestrial path – provides good signal penetration in urban areas.

Frequency Diversity

12.5 MHz CENTERED AT 2326.25 MHz

Space Diversity

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Time Diversity
SDARS Design challenges - 1

- Specific 3-stream system receiver design challenges met by the receiver to overcome key impairments
  - **Soft handover**
    Receiver architecture includes an MRC allowing a soft handover from satellite dominated to terrestrial dominated environments and back, or from dual to single satellite availability and back.
  - **Blocking**
    When the signal for a particular stream is blocked by an obstruction (overpass, tree canopy, etc.), or by an interferer, the receiver recovers acquisition robustly. In most cases, the outage for a particular stream is masked by the diversity inherent in the 3-stream system.
  - **Multi-path**
    With its diversity, FEC and interleaver, the receiver is designed for operation in a severe multipath environment.
  - **Adjacent channel interference**
    Competitor's high power terrestrial transmitters are in adjacent band.
SDARS Design Challenges - 2

- Specific 3-stream system receiver design challenges met by the receiver to overcome key impairments (continued)
  - Large number of channels in limited bandwidth
    - About 60 Music channels, 40 voice channels (128 maximum)
    - Perceptual Audio Coding (PAC) compression used
  - Fast channel change
    - Composite audio stream segmented into 5 clusters of 20 channels each.
      Channel change less than 0.9 s within a cluster, less than 1.8 s across clusters.
  - Differential delays between transmit streams
    - Path delays are different for the 3 streams and compensation must be made. Receiver can compensate for differential delay up to ±170 ms.
  - Access security
    - Encrypted access control subsystem is included
SPACE* System – Composite stream

- Builds composite bit stream for uplink
  - Forward error correction and encryption
  - Statistical multiplexing of audio/data channels
  - Common control channels
- Fault tolerant power supplies and encoding boards

* Streaming of Perceptual Audio Coding and Encryption
Orbits used – and Coverage

Two very distinct types of orbit can be used in SDARS today

– Geostationary orbit (XM and Worldspace chose this orbit)
– Highly inclined elliptical orbit (Sirius chose this orbit)

**Geostationary orbit** provides constant signal level at a given place, but signal level deteriorates as one moves North / South of equator.

- Coverage is good for countries near or close to the equator
- Signal is poor for northern parts of USA and is very poor in Canada.
- Gap Filler Coverage by using terrestrial transmitters - necessary

High power transmitter needed on the XM /Worldspace satellite – since it is about 36000 Km away from earth

Geostationary orbit
(Circular orbit on the equatorial plane)
Orbits used – and Coverage

Two very distinct types of orbit can be used in SDARS today
– Geostationary orbit (XM and Worldspace chose this orbit)
– Highly inclined elliptical orbit (Sirius chose this orbit)

Three Sirius satellites (weight ~ 3,760 Kg each) operate in a egg-shaped orbit ranging from 23,979 Km at the low point to 46,992 Km at the high end, inclined 63.4 degrees.
Sirius Satellite Orbit (highly inclined elliptical orbit)

- Here is a look at the orbital parameters of the Sirius constellation:
  - Inclination 63.4 deg, ±0.5 deg
  - Eccentricity 0.2684 ±0.005
  - Orbit Period 24 Hours (16 + 8 = 24)
  - Relative Phasing 8.0 Hr ±10 minutes
  - Semi-Major Axis 42,164 km
  - Pedigree Radius 24,469 km
  - Apogee Radius 47,102 km
  - RAAN 45.0 deg, 165.0 deg, 285.0 deg
  - Argument of Perigee 270.0 deg ±0.5 deg
  - Apogee Longitude 96.0 deg W ±0.5 deg
  - Mean Anomaly Y deg Y-120.0 deg, Y-290.0 deg
Test Capability

Test Lab for development
- Full equipment suite
- Field impairment simulation
- Arbitrary waveform generation for specific test set ups
- Live Signal based tests

Test Vehicle for mobile field test
- Fully instrumented test
- Vector collection for system status
- Vector Analysis post-test
Two generations of Satellite Radio IC - developed

Gen-1 SDARS Chipset

Gen-2 SDARS Chipset

Present receiver core module are Gen 2 and near credit card sized (RF to data interface)

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Example: Credit Card Size receiver for SDARS - RF chip and baseband

Gen -2 Single Chip Baseband:

Gen 2 + Memory + A/D converter fits into an 85x40x9 mm module
SDARS Receiver Backend

Digital back-end

DIGITAL BASEBAND IC

DUAL A/D

DIGITAL DOWN CONVERSION

TDM DEMODULATOR

TDM DEMODULATOR

DIGITAL DEMODULATOR

OFDM DEMODULATOR

DIFFERENTIAL DELAY COMPENSATION

CLUSTER SYNCH.

CLUSTER SYNCH.

CLUSTER SYNCH.

MRC

Memory

4 SECOND DELAY

to decode

Cluster Descrambler/Deinterleaver

Cluster control

Audio Demux

Audio Channel Select/Decode

Audio Decompress (DSP)

DAP

Control CE-OEM (ARM)

CE-OEM Receiver Subsegment

Audio DAC And Amplifier

Cluster control

Decode

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Receiver Applications Interface
CE-OEM Interface

- Provides I²S Audio interface at 32K, 44.1K and 48K data rates with SPI serial control interface.
- Basic PC based GUI tool – supports development of receiver and user interfaces for specific applications.
- Support for field trials (measurement and characterization) for established routes
- Can alternate between I²S interface or data (Video, HDLC* etc.,) rate of 1.4 Mbps (current). Simultaneous data, audio and video is possible.

*HDLC – High level Digital Link control
Receivers Today

- Present receivers core module is credit card sized (same module is used either at home or in the car)
- Gen –3 card is now under development (common antenna for COFDM and TDM)
Conclusion

- Three major systems of SDARS are in operation today – XM and Sirius in North America (USA, Canada and Mexico) and Worldspace in Europe and Asia. Both XM and Sirius support very high mobility (aircraft speeds).
- Although the FCC auctioned the SDARS bands (2320-2332.5 MHz and 2332.5 – 2345 MHz) in 1997 as Audio Radio, video streaming to the back seat has been demonstrated by Sirius in 2003. Therefore distinction between Radio and TV is therefore not very clear.
- SDARS can provide a broad band streaming of data to individual receivers – this capability offers major potential for mobile data downloading (use the cell phone to request and use the car radio to download files)