FM Stereo with RDS

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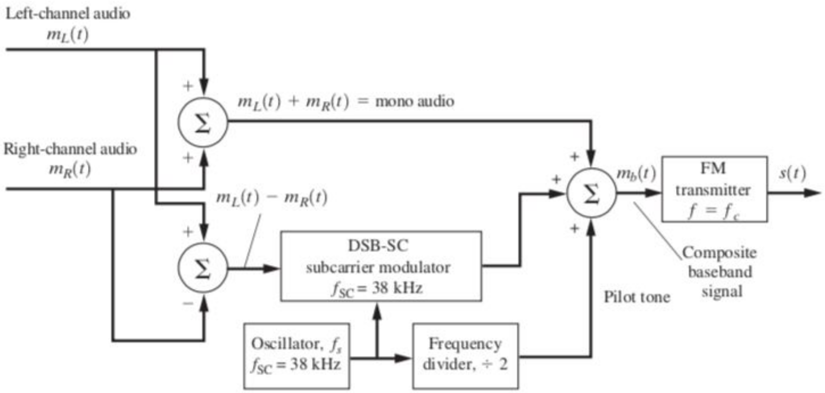
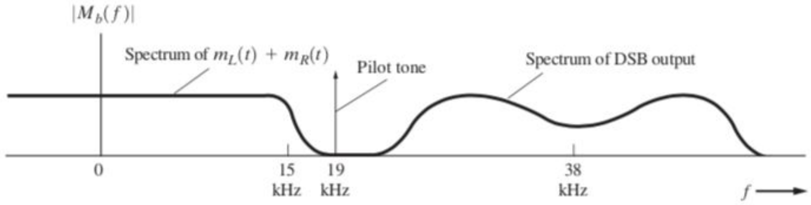
FM Stereo Basics - Transmission

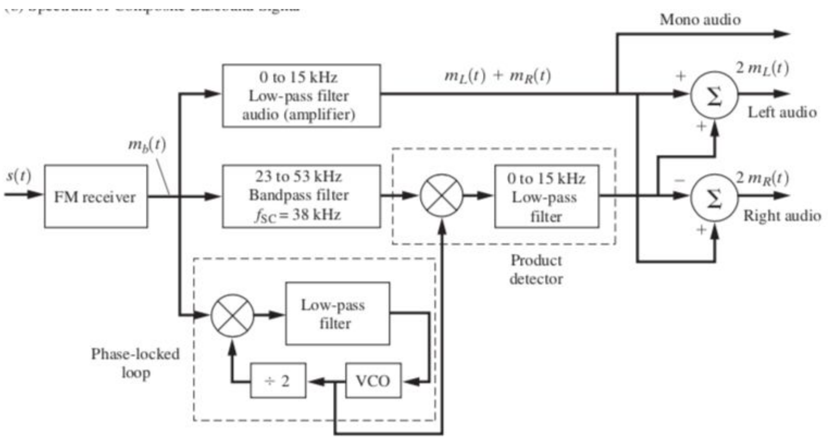
- Two channels provide better sound quality
- Channel sum modulated at baseband
- Channel difference modulates at 38 kHz
- Additional 19 kHz pilot for demodulation
- All summed and transmitted at carrier
- RDS transmitted at 57 kHz





FM Stereo Basics - Reception

- Low pass filtering retrieves mono audio
- Pilot mixed with itself to form 38 kHz pulse
- Used to bandpass filter around difference
- Further filtering isolates difference audio
- Sum and difference audio manipulated to retrieve individual channel audios

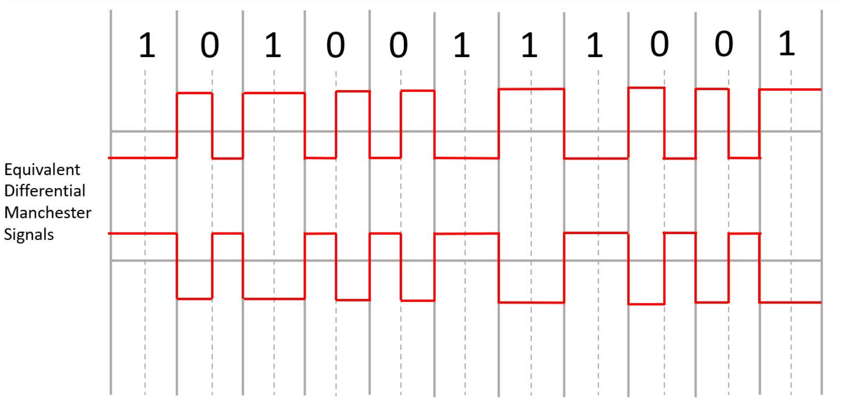


What is RDS?

Standard for embedding digital information in commercial FM broadcasts

Physical Layer [2]

- Differential Manchester (DM) coding embeds data and clock into one signal
- This DM signal is generated at an 1,187.5 Hz rate
- A cosine filter is applied to bandlimit this DM signal
- DSB-SC modulated onto a 57 kHz subcarrier, locked either in phase or in quadrature to the third harmonic of the 19 kHz pilot tone (±10°)
- Total bandwidth of 2.375 kHz at bandpass



Differential Manchester coding [3]

- Transition at the beginning of each interval representing a new bit (embedded clock)
- A transition in the middle of the interval represents a "0" bit, otherwise it is a "1"
- Same data regardless of polarity!

What is RDS?

Data link layer [2]

- The largest data unit in RDS is called a “group”
- Four 26 bit “blocks” form a group
- Each block contains 16 data bits and 10 error correction bits

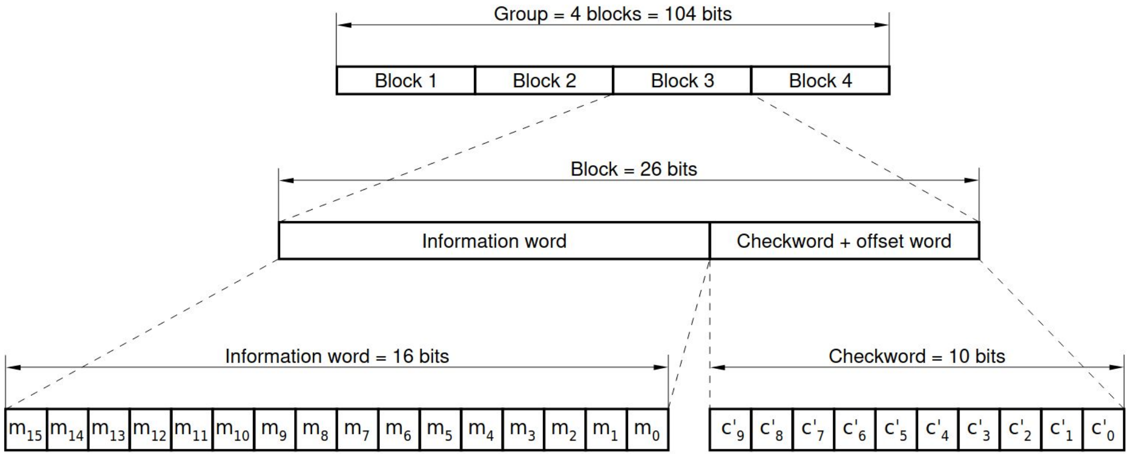
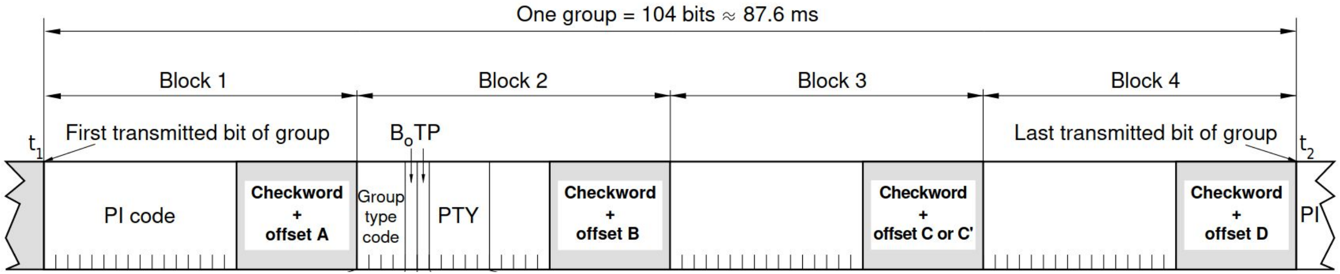


Figure 8: Structure of the baseband coding

What is RDS?



Data link layer [2]

- First block in each group is the program identification (PI) code: four character hex code similar to a callsign
- First four bits of the second block specify the application of the group, for example:
    - Basic tuning and switching information
    - RadioText (typically song and artist name, up to 64 characters)
    - Clock time and date
    - Traffic/weather alerts
    - etc.
- Second block also identifies whether a traffic alert is present (TP) and the “program type” (PTY), a code indicating genre or format

3.1.5.1 Type 0 groups: Basic tuning and switching information

The repetition rates of type 0 groups must be chosen in compliance with 3.1.3.

Figure 12 shows the format of type 0A groups and figure 13 the format of type 0B groups.

Note: Four type 0A groups are required to transmit an 8 character "programme service"

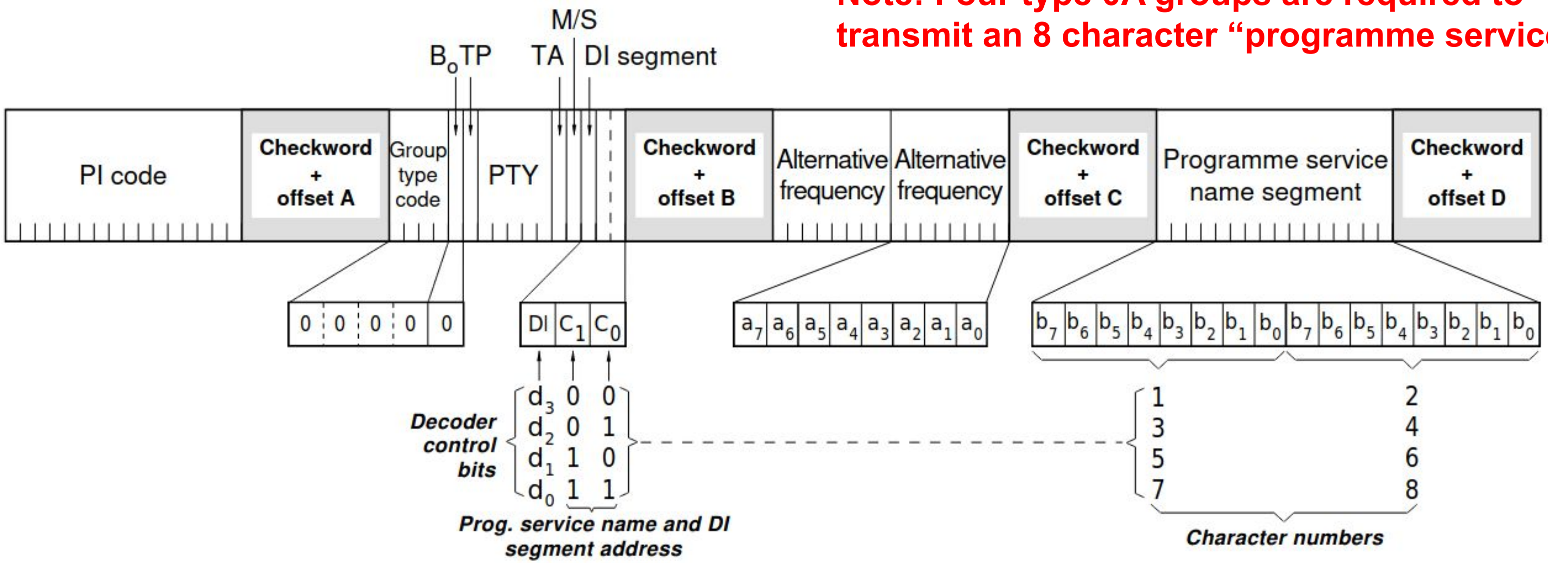


Figure 12: Basic tuning and switching information - Type 0A group

3.1.5.3 Type 2 groups: RadioText

Figure 16 shows the format of type 2A groups and figure 17 the format of type 2B groups.

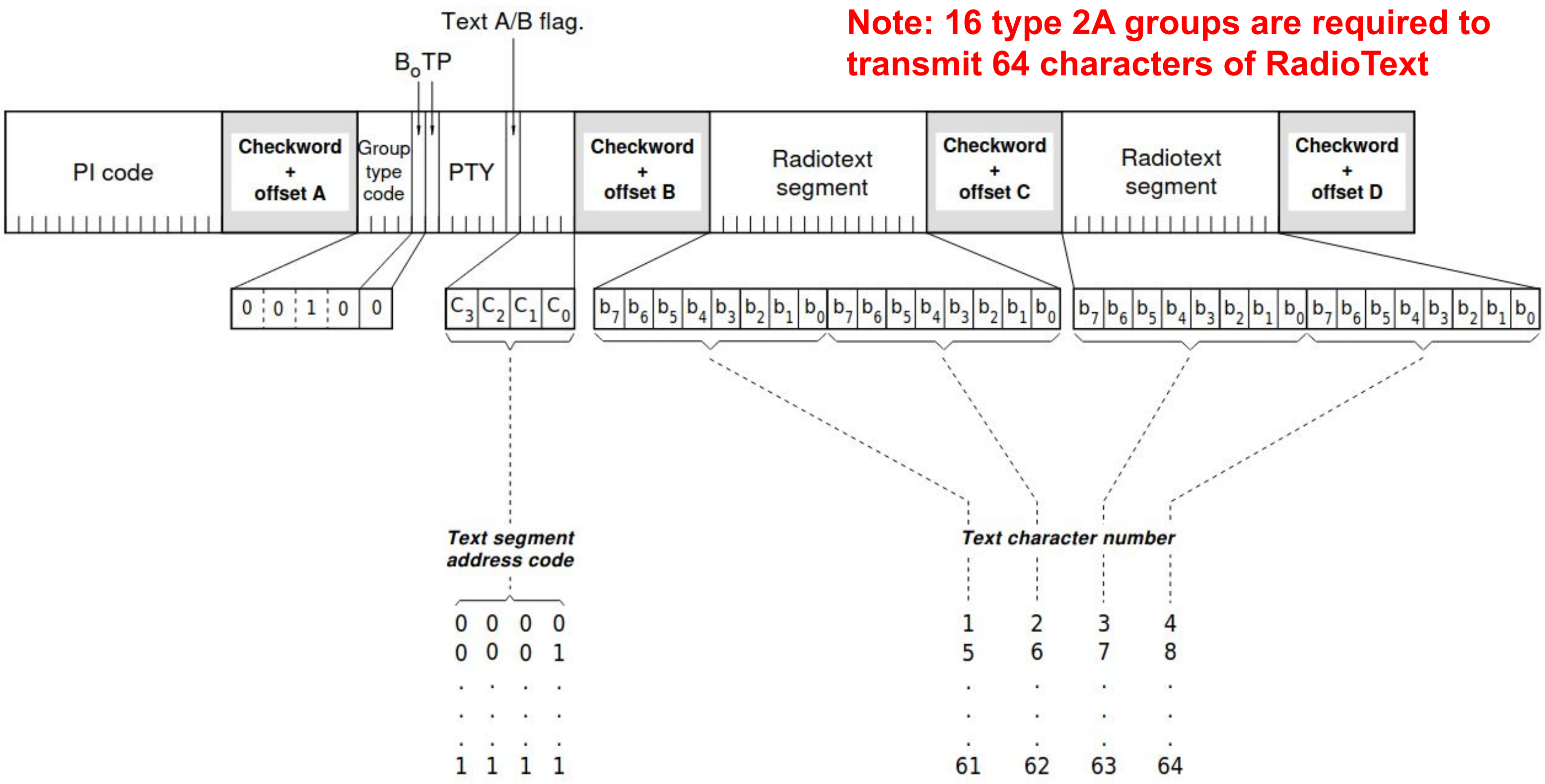


Figure 16: RadioText - Type 2A group

GRC and PLUTO-SDR Implementation

- A 2-channel (stereo) WAV file source was used
- Transmission and reception of the FM stereo signal was done using built-in blocks
- The gr-rds library was used to encode and decode RDS signals
  - Ubuntu Linux was used, as the library appeared to not be compatible with GRC installations on Windows
  - A virtual machine proved to not be fast enough, so Ubuntu was booted natively from portable hard disks
- Transmission occurred on an unused frequency in the U.S. FM radio band (88.1 - 107.9 MHz). This is legal for low power transmissions (typically less than 200 feet) [4]
- VHF “rabbit ears” style antennas were used, as the included PLUTO-SDR antennas were insufficient in the 88.1 - 107.9 MHz range, even when only a few inches apart
- Constants (e.g., the gain of each subcarrier) were adjusted empirically for optimal stereo audio and RDS performance

Results and Demonstration

FM stereo & RDS transmitter worked well with both another PLUTO-SDR and commercial FM radio receivers at short range (<5 ft)

Three receiver varieties were tested, with different methods of extracting the 57 kHz RDS subcarrier

1. Using a “Frequency Xlating FIR Filter” block set to 57 kHz, which produces a complex baseband output
    - This offered the best RDS performance
2. Multiplying the 19 kHz pilot by itself thrice to produce a 57 kHz signal for demodulating the RDS subcarrier
    - This worked for some stations, but not for others. Probably only ones where the RDS subcarrier was in phase with the third harmonic of the 19 kHz pilot. This only covered the “in phase” case and not the optional “in quadrature” case mentioned in the RDS standard [2]
3. Multiplying the 19 kHz pilot by itself three times to produce a 57 kHz signal, then phase delaying it by ~90° to quadrature demod the RDS signal
    - This worked for stations method 2 did not work for, but not as well as method 1 on weak stations

References

[1] L. W. Couch, *Digital and Analog Communication Systems*. Prentice Hall, 2012

[2] European Committee for Electrotechnical Standardization, *Specification of the radio data system (RDS) for VHF/FM sound broadcasting in the frequency range from 87,5 to 108,0 MHz*. 1998. http://www.interactive-radio-system.com/docs/EN50067_RDS_Standard.pdf

[3] Teledyne LeCroy, Inc., *What Is Differential Manchester Encoding?*. 2021. https://blog.teledynelecroy.com/2021/11/what-is-differential-manchester-encoding.html

[4] Federal Communications Commission. *Low Power Radio - General Information*. 2017. https://www.fcc.gov/media/radio/low-power-radio-general-information