Digital communication exam (2019)

J.-M Friedt, March 13, 2019

Connexion internet interdite, téléphones portables interdits, communications interdites, réflexion autorisée.

1 CC1101 transceiver

The Texas Instruments CC1101 transceiver, despite becoming an aging component, is still widely used in many sub-GHz wireless digital communication peripherals. A screenshot of the introduction of its datasheet is exhibited in Fig. 1.

Based on the information provided in the datahsheet

1. Can two chips fitted with isotropic antennas communicate at a range of 10 km ? If so, under what condition ? Justify.

2. Can two chips fitted with isotropic antennas communicate at a range of 50 km ? If so, under what condition ? Justify.

3. What solution might be used to improve communication bandwidth in the case of the weakest link budget ?

4. What is the maximum power transmitted by the chip in a linear scale ?

5. Considering the chip is powered with a 3.2 V battery, comment on the power consumption efficiency on the chip with respect to the emitted radiofrequeny power, assuming that the current drawn by the chip does not significantly vary between reception and transmission.

RF Performance

- High sensitivity
  - -116 dBm at 0.6 kBaud, 433 MHz, 1% packet error rate
  - -112 dBm at 1.2 kBaud, 868 MHz, 1% packet error rate
- Low current consumption (14.7 mA in RX, 1.2 kBaud, 868 MHz)
- Programmable output power up to +12 dBm for all supported frequencies
- Excellent receiver selectivity and blocking performance
- Programmable data rate from 0.6 to 600 kbps
- Frequency bands: 300-348 MHz, 387-464 MHz and 779-928 MHz

Analog Features

- 2-FSK, 4-FSK, GFSK, and MSK supported as well as OOK and flexible ASK shaping
- Suitable for frequency hopping systems due to a fast settling frequency synthesizer; 75 µs settling time
- Automatic Frequency Compensation (AFC) can be used to align the frequency synthesizer to the received signal centre frequency
- Integrated analog temperature sensor

Low-Power Features

- 200 nA sleep mode current consumption
- Fast startup time; 240 µs from sleep to RX or TX mode (measured on EM reference design [1] and [2])
- Wake-on-radio functionality for automatic low-power RX polling
- Separate 64-byte RX and TX data FIFOs (enables burst mode data transmission)

General

- Few external components; Completely on-chip frequency synthesizer, no external filters or RF switch needed
- Green package: RoHS compliant and no antimony or bromine
- Small size (QLP 4x4 mm package, 20 pins)
- Suited for systems targeting compliance with EN 300 220 (Europe) and FCC CFR Part 15 (US)
- Suited for systems targeting compliance with the Wireless MBUS standard EN 13757-4:2005
- Support for asynchronous and synchronous serial receive/transmit mode for backwards compatibility with existing radio communication protocols

Figure 1: Introductory section of the CC1101 datasheet

2 Signal modulation and content identification

Two signals are emitted in the 868 MHz Industrial, Scientific and Medical band, lying in the 865 to 870 MHz range. In all cases, the signal being transmitted is a *sine wave* modulating the carriers. Using the DVB-T receivers acting as general purpose software defined radio receivers, we wish to investigate the properties of the transmitted signals and identify the characteristics of the modulation scheme in order to extract the transmitted information.

6. identify the center frequency of each emission: provide the answer and how the result was obtained (flowchart),

7. identify the fine structure of the narrowest modulation mode. How many spectral features can you identify ? Describe these features (frequency spacing, power). Justify how the fine structure of the spectrum is obtained.

8. the two modulations schemes used are frequency modulation and amplitude modulation. Considering the observed spectral bandwidths, which signal is amplitude modulated ? which signal is frequency modulated ?

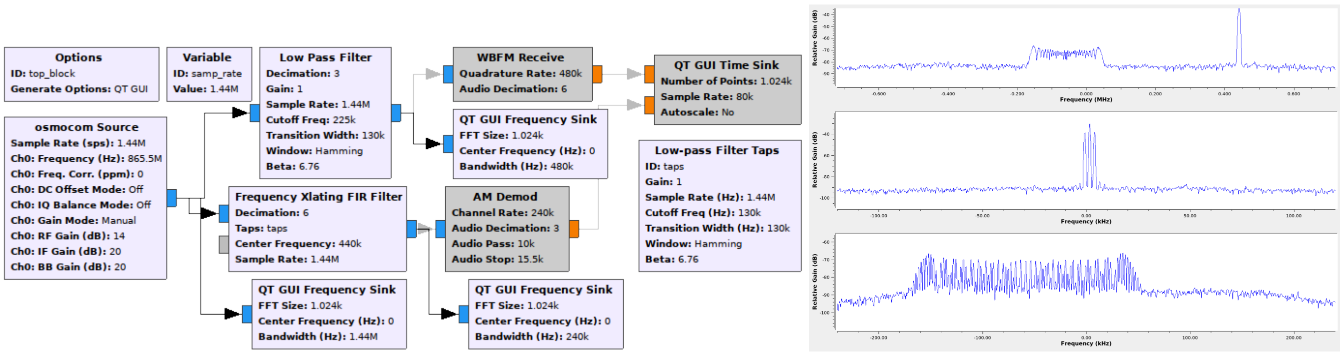
9. identify the frequency of the modulating signal, i.e. transmitted on the amplitude modulated carrier. Justify by providing the signal processing flowchart.

10. identify the frequency of the modulating signal, i.e. transmitted on the frequency modulated carrier. Justify by providing the signal processing flowchart.

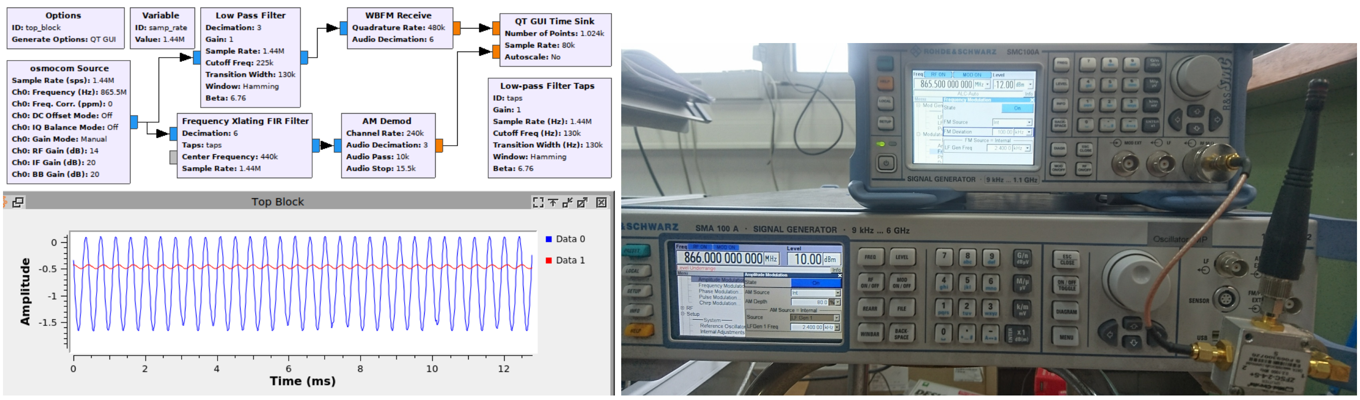
11. Display the demodulated output of **both channels simultaneously** a QT GUI Time Sink.

Réponses

1. 10 km=10^4 m$\Rightarrow$ FSPL(300 MHz) = 102 dB & FSPL(900 MHz) = 111 dB donc en émettant +12 dBm, on reçoit toujours plus que -112 dBm (limite de détection à 868 MHz)
2. 50 km=$5 \cdot 10^4$ m $\Rightarrow$ FSPL(300 MHz) = 116 dB & FSPL(900 MHz) = 125 dB donc en émettant +12 dBm, la puissance reçue à 300 MHz est -104 dBm > -112 dBm mais à 900 MHz on a $+12-125=-113$ dBm<-112 dBm (limite de détection) donc soit il faut se mettre au débit le plus faible, soit la fréquence la plus basse pour communiquer au débit le plus élevé
3. antenne directive ferait profiter du gain d'antenne dans la direction de la liaison
4. $10^{12/10}=10^{1,2}=16$ mW
5. $3,2$ V$\times$15 mA=50 mW v.s 16 mW de puissance radiofréquence émise, soit une efficacité de 32%.
6. 865,5 et 866 MHz.
7. La décimation permet de zoomer sur le spectre et d'en observer la structure fine. Nous observons trois raies à -0,8 kHz(-25 dB), 1,6 kHz (-17 dB) et 4,0 kHz (-24,7 dB). Cette structure laisse fortement penser à une porteuse décalée de l'écart entre oscillateur émetteur et récepteur (600 Hz) et deux raies latérales d'une modulation d'amplitude.
8. Une modulation est fine (centrée sur 866 MHz), l'autre (autour de 865,5 MHz) présente un large encombrement spectral. La FM est en modulation WBFM et occupe le spectre le plus large. L'AM ne présente que deux raies de part et d'autre de la porteuse, puisque le spectre d'une sinusoïde modulant une porteuse est formé de deux raies latérales.
9. 2400 Hz
10. 2400 Hz
11. L'ajout d'un `Xlating FIR Filter` permet d'amener chaque mode de trasmission en bande de base autour de la fréquence nulle et donc de démoduler ce signal.



Gauche : flux de traitement avec acquisition et affichage des spectres large bande (haut), zoom sur la modulation d'amplitude (milieu) et de fréquence en mode large WBFM (bas).



Gauche : signaux démodulés présentant les sinusoïdes à 2400 Hz. Droite : montage expérimental.