IEEE P802.11
Wireless LANs

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| Frequency Regulation Chapter for AMP TIG Report |
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Abstract

This document provides draft input to the AMP TIG report.

# 5. Frequency Regulation

Besides the technical feasibility, also the frequency regulation plays an important role.

For the USA, the relevant frequency regulation is given in FCC 15.247.

In Europe, wireless systems should follow the so-called “ETSI Harmonised Standards”. Theoretically, following these harmonized standards is not a legal requirement. However, the introduction of new devices to the European market is significantly more simple if devices follow these harmonized standards.

If required, it is also possible to extend the current frequency regulation as well as the ETSI harmonized standards. However, such process may last many years and could not lead to satisfactory results. An example for such process is IEEE 802.11ah: The process in Europe took many years and the frequency regulation only allow for a small subset of the modes (e.g. only 1MHz bandwidth) with strong duty cycle requirements (≤2.5% for end-devices), and a maximum transmit power of 25mW. In addition, the harmonized standard is still under development.

Generally, the frequency regulation for the existing Std IEEE 802.11 is well known. The frequency regulation for IEEE 802.11 typically assumes a high bandwidth with a limited power spectral density. However, this may change, especially in case of wireless power transfer. This wireless power transfer is mandatory for backscatter modulation, and if the AMP device is not equipped with any energy storage capabilities. Furthermore, it also can be used to charge a capacitor inside an AMP device. For this reason, high transmits powers are required for energizing the AMP devices. The calculations in the previous chapters assume transmit powers in the order of 30dBm EIRP (equivalent isotropically radiated power).

The following sections will review the frequency regulation in the USA and the “ETSI Harmonised Standards”.

Frequency Regulation in FCC 15.247:

The frequency regulation in FCC 15.247 covers both relevant frequency bands, i.e. 902-928MHz, and 2400-2483.5MHz. The maximum electrical transmit power is limited by 1W, i.e. 30dBm. Additionally, antennas with up to 6dBi gain can be used. This offers an EIRP at the AP of up to 36dBm.

Potential further restrictions – depending on the spectral characteristics of the signal – are mandatory frequency hopping over up to 50 channels and a maximum dwell time of 400ms.

In summary, the frequency regulation according to FCC 15.247 should support all aforementioned techniques. The maximum EIRP for wireless power transfer to is up to **36dBm EIRP (i.e. 4W)**.

ETSI Harmonised Standards

The situation concerning the frequency regulation is significantly more complex in Europe. There exist multiple harmonized standards for the desired frequency bands. These standards assume different characteristics of the transmit signal. The following sub-sections will review the situation for the 2.4GHz and the sub-GHz bands.

ETSI Harmonised Standards in the 2.4GHz band

**ETSI EN 300 328** covers “Wideband transmission systems; Data transmission equipment operating in the 2,4 GHz band; Harmonised Standard for access to radio spectrum”. This standard especially covers IEEE 802.11, referred as wide-band data transmission. Furthermore, it covers frequency hopping spread spectrum systems (FHSS) (e.g. Bluetooth). The frequency range is 2400 to 2483.5MHz. The maximum transmit power is 100mW EIRP, i.e. 20dBm.

Additional restrictions apply in case of a transmit powers higher than 10dBm EIRP:

For wide-band transmissions, the maximum power spectral density is limited to 10dBm/MHz.

FHSS systems have a maximum transmit TX-sequence time of 5ms, followed by a TX-gap time of 5ms. Additionally, FHSS have to follow additional restrictions concerning the hopping frequency separation.

**ETSI EN 300 440** covers “Short Range Devices (SRD); Radio equipment to be used in the 1 GHz to 40 GHz frequency range; Harmonised Standard for access to radio spectrum”. This standard covers communication systems not covered by ETSI EN 300 328 and RFID in the 2.4GHz band covering 2400 to 2483.5MHz. Unspecific communication devices may transmit with a maximum power of 10dBm EIRP without any additional restrictions.

RFID is allowed in the frequency range between 2446 and 2454MHz resulting in a maximum bandwidth of 8MHz. The maximum transmit power is 4W EIRP (i.e. 36dBm). However, 4W EIRP “shall by technical means be restricted to in building use” und has duty cycle restrictions of 15%. These restriction do not apply for transmit powers of 500mW EIRP (i.e. 27dBm). However, even in this case the frequency regulation mandates an antenna with ±45 degrees horizontal beamwidth in addition to a side-lobe attenuation of equal or more than 15dB. Furthermore, it requires “physical protection (e.g. antenna dome) which dimension limits a power transfer from the RFID antenna to a quarter wave matched dipole at positioned at an extreme close proximity to +15dBm”.

Summarizing the findings for the European harmonized standards in the 2.4GHz band:

* No restrictions up to **10dBm** EIRP (i.e. 10mW).
* **20dBm** EIRP (i.e. 100mW) in case of frequency hopping or wide-band signals
* **27dBm** EIRP (i.e. 500mW) with directive antennas (most likely **not suitable for mobile phones as energizers**), bandwidth of 8MHz only, can be extended to **36dBm** EIRP (i.e. 4W) for stationary indoor use (impractical for private use)

ETSI Harmonised Standards in the 863 to 870 MHz and 915 to 921 MHz band

NOTE: For sub-GHz ETSI uses the ERP (equivalent radiated power) instead of the EIRP (equivalent isotropically radiated power). A transmitter with 1mW ERP (i.e. 0dBm) is identical to a transmitter with 1.64mW EIRP (2.15dBm).

**ETSI EN 302 208** covers “Radio Frequency Identification Equipment operating in the band 865 MHz to 868 MHz with power levels up to 2 W and in the band 915 MHz to 921 MHz with power levels up to 4 W; Harmonised Standard for access to radio spectrum”.

The frequency range between 865 to 867MHz defines four channels, each having a bandwidth of 400kHz. The maximum transmit power is 2W ERP (i.e. 35.15dBm EIRP) with antennas having a beamwidth ≤90°. For omni-directional antennas the maximum power is limited to 500mW ERP (i.e. 29.14dBm EIRP). The maximum transmit time is 4s, followed by a break of at least 100ms. The maximum transmit power of the tags is -20dBm ERP in addition to a maximum bandwidth of 400kHz in one of the four available channels.

The frequency range of 915 to 921 MHz also defines four channels. However, it is currently available in few European countries only. Power levels of up to 4W ERP (i.e. 38.17dBm EIRP) require antennas having a beamwidth ≤90°. For omni-directional antennas, the maximum power is limited to 1W ERP (i.e. 32.15dBm EIRP). The maximum transmit time is again 4s, followed by a break of at least 100ms. The maximum transmit power of the tags is -10dBm ERP in addition to a maximum bandwidth of 800kHz in one of the four available channels.

**ETSI EN 300 220-2** covers “Short Range Devices (SRD) operating in the frequency range 25 MHz to 1 000 MHz; Part 2: Harmonised Standard for access to radio spectrum for non specific radio equipment”.

Relevant in the scope of this document is the frequency range 863 to 870MHz and 915 to 921 MHz.

Generally, the aforementioned frequency ranges are divided into many bands with different transmit power, duty cycle, or other restrictions. Annex B and C in ETSI EN 300 220-2 give a complete overview. In addition, only the bands defined in annex B (only 863 to 870MHz) are harmonized within the European Union. The frequencies between 915 and 921MHz are available in few European countries only.

The maximum transmit power is typically limited to 10mW or 25mW ERP. The only frequency band offering higher transmit powers is band O between 869.4 and 869.65MHz. It has a bandwidth of 250kHz and offers a maximum transmit power of 500mW ERP (i.e. 29.14dBm EIRP). This band is furthermore limited by a duty cycle of ≤10%. The typical application for this frequency band is the downlink of Low Power Wide Area Networks (LPWAN), e.g. LoRaWAN. Due to the high popularity of LPWAN the channel is already highly occupied in many areas. Consequently, it may be less suited for the uplink from the AMP device to the AP. However, the AP device could also use other bands in the 863 to 870MHz frequency range for the uplink to avoid interference into the uplink.

Generally, the AMP devices also has to follow the frequency regulation. This may e.g. cause issues wrt. the resulting signal bandwidth in case of backscatter-modulation.

**ETSI EN 303 659** is currently under development. It will cover “Short Range Devices (SRD) in Data Networks; Radio equipment to be used in the frequency ranges 865 MHz to 868 MHz and 915 MHz to 919,4 MHz with power levels ranging up to 500 mW e.r.p.; Harmonised Standard for access to radio spectrum”. This will also cover IEEE 802.11ah.

The frequency regulation already allocated the corresponding frequency bands. According to the “Commission Implementing Decision (EU) 2019/1345 of 2 August 2019” the frequency regulation allows for 500mW ERP (i.e. 29.14dBm EIRP) if the channel bandwidth is ≤ 200kHz. The available four channels are identical to the four channels defined for RFID usage in ETSI EN 302 208. Additional restrictions are a duty cycle of 10% for AP and 2.5% otherwise. Furthermore, also systems with a bandwidth of up to 1MHz are possible, e.g. IEEE 802.11ah. The parameters are mainly identical to the parameters of the 200kHz mode, but the maximum transmit power is limited to 25mW ERP (i.e. 16.13dBm EIRP).

In addition, the AMP devices have to follow the frequency regulation, which again may cause issues wrt. the resulting signal bandwidth in case of backscatter-modulation.

Summarizing the findings of the European harmonized standards in the sub-GHz bands:

* Highly fragmented into many different bands with different parameters (e.g. duty cycle, transmit power, bandwidth)
* **16.13dBm** EIRP (i.e. 25mW ERP) for 1MHz wide channels with duty cycle limitations
* **29.14dBm** EIRP (i.e. 500mW ERP) for systems with up to 200kHz bandwidth with duty cycle limitations, one channel with up to 250kHz bandwidth
* **35.15dBm** EIRP (i.e. 2W ERP) for RFID systems with **directive antennas**, bandwidth limited to 200kHz for downlink and 400kHz for uplink
* **38.17dBm** EIRP (i.e. 4W ERP) for RFID systems with **directive antennas** in bands that are **only available in some EU countries**, bandwidth limited to 400kHz for downlink and 800kHz for uplink

Concluding the review of the frequency regulation, the intended use-cases can be covered. However, especially the European frequency regulation limits the available bandwidth in case of high transmit powers to approx. 30dBm, which is the typically minimum assumed transmit power to energize the AMP devices. This will impose restrictions, especially on the available bandwidth and the use of backscatter modulation. Furthermore, technological restrictions for 2.4GHz RFID in Europe (e.g. antenna directive pattern) may hinder specific use-cases in this frequency band.