Proposal for Revision of Modulations in UN ECE R10 Rev.7

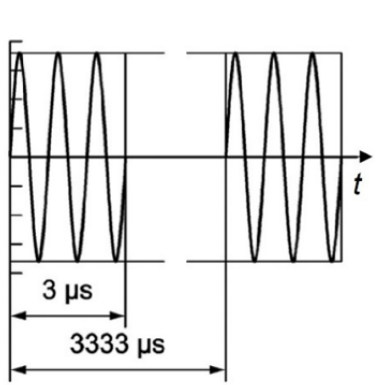
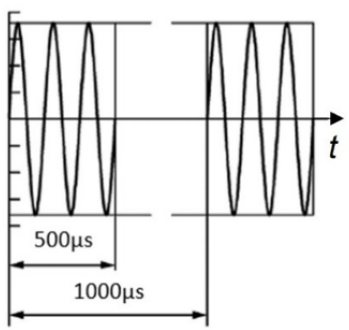
1. Proposal

Proposal for Revision of Modulations and Their Frequency Allocation

Reference document: IWG-EMC-33-05e

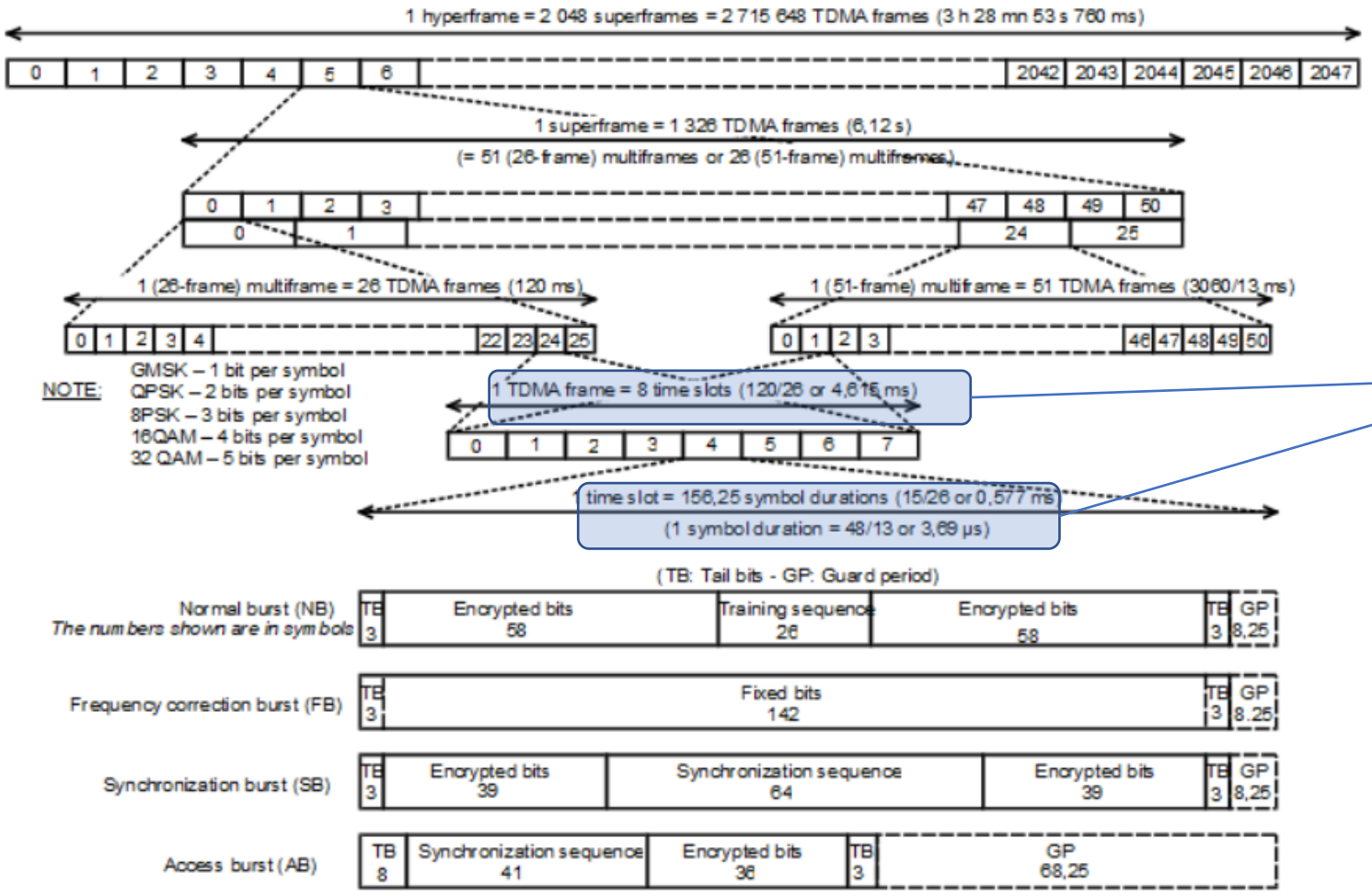
In regard to recent discussions in ISO/TC22/SC32/WG3 (during October 2022 last meeting), it has been agreed to propose for on-going revision of ISO 11451-1 and ISO 11452-1, the following modulations within the R10 applicative frequency range

- AM 1kHz 80% : 20 MHz to 800 MHz;
- PM type 2 with ton = 3 µs and period = 3333 µs : 2,7 GHz to 3,1 GHz
- PM type 3 with ton = 500 µs and period = 1000µs : 800 MHz – 2,7 GHz and 3,1 GHz – 6 GHz

	
c) PM type 2 signal	**d) PM type 3 signal**

2. Technical Rationale and References

2G



Channel bandwidth: 200kHz

Frame length: 4.16ms = 217Hz
Slot length: 577µs

Derivation:
The ratio of slot length (577 µs) to frame length (4.16 ms) corresponds to PM (577µs, 4.16ms).

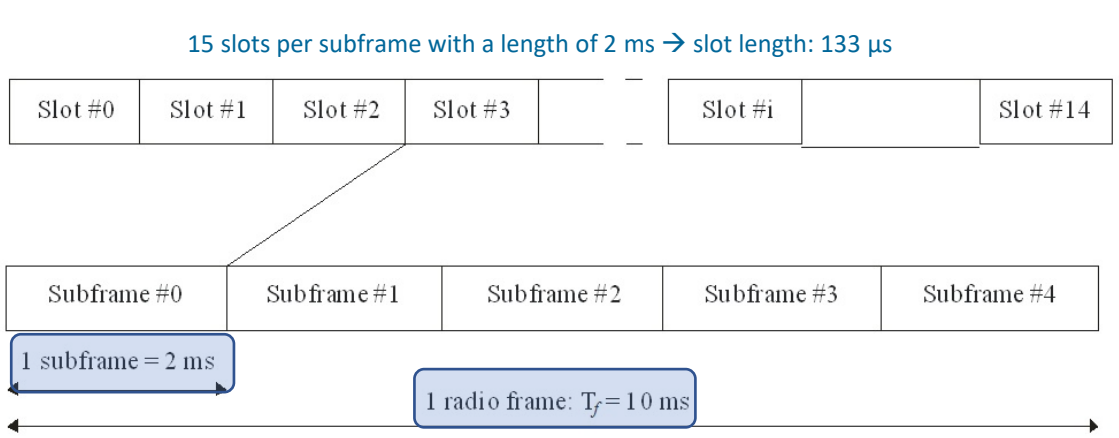
Conclusion:
PM (217Hz = 4.16 ms, 577 µs) is suitable to emulate 2G.

Source: [GSM TDMA Frame Parameterization for Waveform Generation - MATLAB & Simulink (mathworks.com)]

3G

Channel bandwidth: 5 MHz

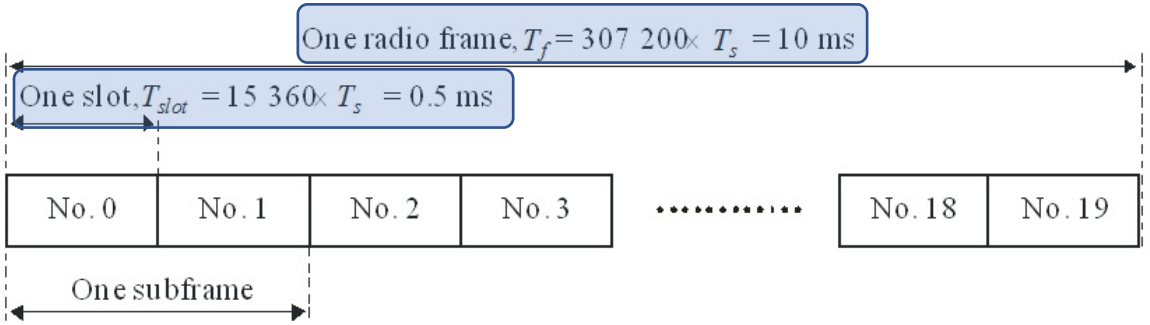
Basic frame structure



Frame length: 10 ms, subframe lengths 2 ms, slot length: 133 µs

Derivation:
The ratio of subframe (2 ms) to frame (10 ms) results in a duty cycle of 20 %. Taking the subframe length (2 ms) as a reference, this results in PM (500 Hz, 20 % duty cycle).

Frame structure type 1 for FDD



1 subframe consists of 2 slots with a length of 0.5 ms each → subframe length = 1ms

Frame length: 10 ms, subframe length: 1ms, slot length: 500µs

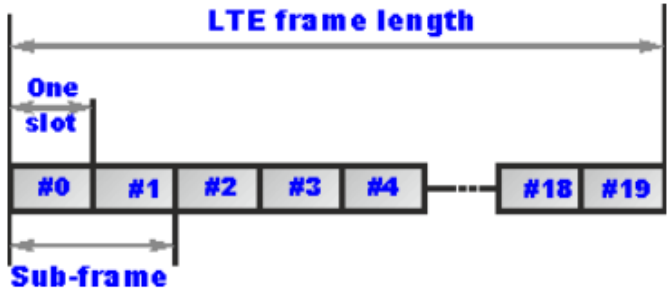
Derivation:
The ration of subframe (1 ms) to frame (10 ms) results in a duty cycle of 10 %. Taking the subframe length (1 ms) as a reference, this results in PM (1 kHz, 10 % duty cycle).

Conclusion and Harmonizing Proposal: In order to account for a superposition of signals (→ energy density) and existing standards (e.g. MIL-STD 461G), PM (1kHz, 50% Duty Cycle) is suitable to emulate 3G.
Alternatively, a 5 MHz AWGN signal would also be suitable, taking the channel bandwidth into consideration.

Source: UMTS detailed description (3gpp.org), 3G UMTS Frequency Bands: UARFCN » Electronics Notes (electronics-notes.com)

4G - LTE

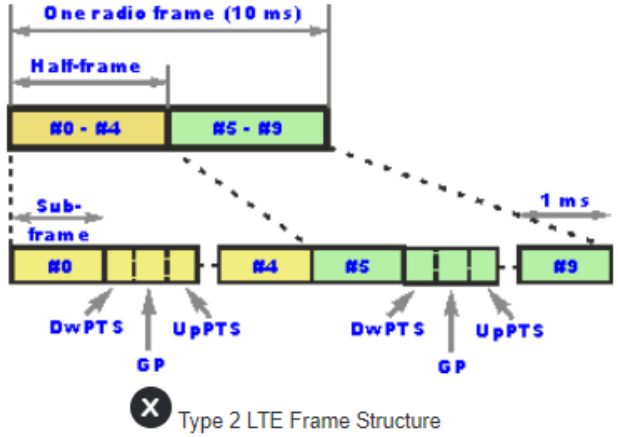
LTE Frame Structure Type 1 (FDD)



Type 1 LTE Frame Structure

Frame length: 10 ms
(20 slots per frame with duration of 500µs each)
Sub-frame length: 1 ms
(2 slots per subframe with duration of 500µs each)
Slot length: 500 µs

LTE Frame Structure Type 2 (TDD)



Type 2 LTE Frame Structure
(shown for 5ms switch point periodicity).

Frame length: 10ms
(consisting of 10 sub-frames)
Sub-frame length: 1 ms

Bandwidth
1.4 MHz
3 MHz
5 MHz
10 MHz
15 MHz
20 MHz ← max. bandwidth

Derivation:
The ration of subframe (1 ms) to frame (10 ms) results in a duty cycle of 10%. Taking the subframe length (1 ms) as a reference, this results in PM (1 kHz, 10 % duty cycle).

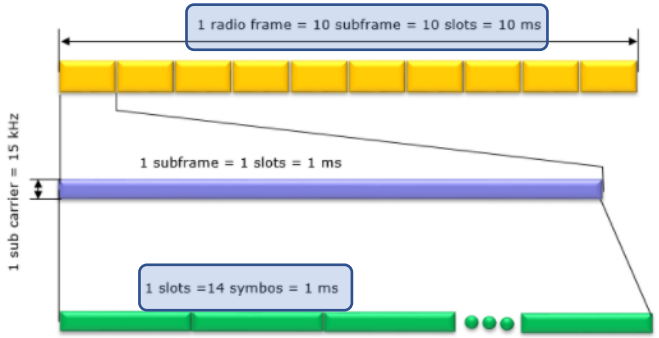
Conclusion and Harmonizing Proposal: In order to account for a superposition of signals (→ energy density) and existing standards (e.g. MIL-STD 461G), PM (1kHz, 50% Duty Cycle) is suitable to emulate 4G (LTE).
Alternatively, a 20 MHz AWGN signal would also be suitable, taking the channel bandwidth into consideration.

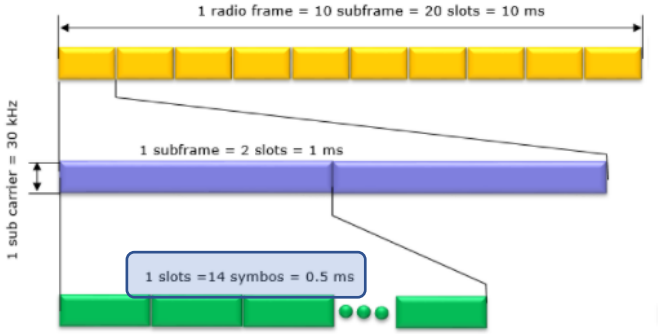
Sources: LTE Frame Structure: Type 1 Type 2 » Electronics Notes (electronics-notes.com), LTE Physical Layer Overview (keysight.com)

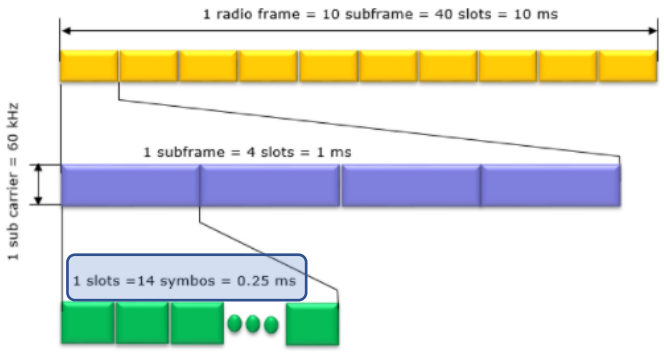
5G

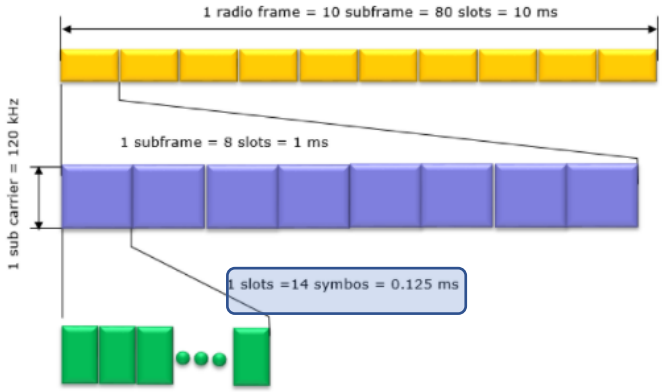
Note: As UN ECE R10 Rev.7 only intends to cover radiated immunity up to 6 GHz, a 400 MHz AWGN is not (yet) relevant for 24.25 - 52.6 GHz.

LTE carriers are narrower in bandwidth, up to 20 MHz maximum that can be aggregated together to create a channel bandwidth up to 100 MHz in LTE-Advance, or up to 640 MHz in LTE-Advanced Pro. In comparison, 5G NR maximum carrier bandwidth is up to 100 MHz in frequency range 1 (FR1: 450 MHz to 6 GHz), or up to 400 MHz in frequency range 2 (FR2: 24.25 GHz to 52.6 GHz) that can be aggregated with a maximum bandwidth of 800 MHz.





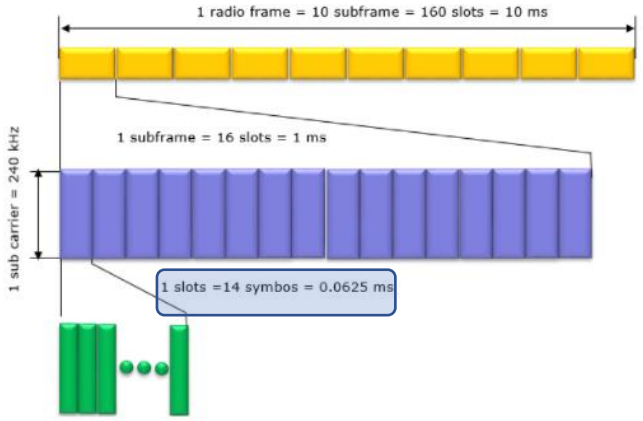




Frame length: 10ms, sub-frame length: 1ms,
slot length: depends on subcarrier spacing (1ms to 62.5µs)

Derivation:
The ration of subframe (1 ms) to frame (10 ms) results in a duty cycle of 10%. Taking the subframe length (1 ms) as a reference, this results in PM (1 kHz, 10 % duty cycle).

Conclusion and Harmonizing Proposal: In order to account for a superposition of signals (→ energy density) and existing standards (e.g. MIL-STD 461G), PM (1kHz, 50% Duty Cycle) is suitable to emulate 5G. Alternatively, a 100 MHz AWGN signal would also be suitable, taking the channel bandwidth into consideration.



Source: 5G NR Frame Structure - 5G Networks (5g-networks.net), Understanding 5G New Radio Bandwidth Parts | Keysight Blogs

WLAN/WIFI

	IEEE 802.11 (obsolete and deprecated)	IEEE 802.11 b	IEEE 802.11 a/h/j	IEEE 802.11 g	IEEE 802.11 n	IEEE 802.11 ac	IEEE 802.11 ax
	Wi-Fi™ 1	Wi-Fi™ 2		Wi-Fi™ 3	Wi-Fi™ 4	Wi-Fi™ 5	Wi-Fi™ 6
Release date	1997	1999	1999	2003	2009	2013	2019
Frequency bands	2.4 GHz	2.4 GHz	5 GHz	2.4 GHz	2.4 GHz, 5 GHz	2.4 GHz, 5 GHz	2.4 GHz, 5 GHz
Frequency range	2.400 GHz - 2.4835 GHz	2.400 GHz - 2.4835 GHz	5.150 GHz - 5.350 GHz 5.725 GHz - 5.850 GHz	2.400 GHz - 2.4835 GHz 5.150 GHz - 5.350 GHz 5.725 GHz - 5.850 GHz	2.400 GHz - 2.4835 GHz 5.150 GHz - 5.350 GHz 5.725 GHz - 5.850 GHz	2.400 GHz - 2.4835 GHz 5.150 GHz - 5.350 GHz 5.725 GHz - 5.850 GHz	2.400 GHz - 2.4835 GHz 5.150 GHz - 5.350 GHz 5.725 GHz - 5.850 GHz
Channel bandwidth	22 MHz	22 MHz	20 MHz	20 MHz	20 MHz / 40 MHz	20 MHz / 40 MHz / 80 MHz / 160 MHz	20 MHz / 40 MHz / 80 MHz / 160 MHz
Maximum throughput	2 Mbps	4 Mbps	54 Mbps	54 Mbps	600 Mbps	6.8 Gbps	100 Gbps
Modulation	Frequency Hopping Spread Spectrum (FHSS), Direct Sequencing Spread Spectrum (DSSS)	Direct Sequencing Spread Spectrum (DSSS)	Orthogonal Frequency Division Multiplexing (OFDM)	Orthogonal Frequency Division Multiplexing (OFDM)	Orthogonal Frequency Division Multiplexing (OFDM)	Orthogonal Frequency Division Multiplexing (OFDM)	Orthogonal Frequency Division Multiplexing (OFDM)
			Subcarrier modulations: Binary Phase Shift Keying (BPSK), Quaternary Phase Shift Keying (QPSK), Quadrature Amplitude Modulation (16 QAM, **64 QAM**)	Subcarrier modulations: Binary Phase Shift Keying (BPSK), Quaternary Phase Shift Keying (QPSK), Quadrature Amplitude Modulation (16 QAM, **64 QAM**)	Subcarrier modulations: Binary Phase Shift Keying (BPSK), Quaternary Phase Shift Keying (QPSK), Quadrature Amplitude Modulation (16 QAM, **64 QAM**)	Subcarrier modulations: Binary Phase Shift Keying (BPSK), Quaternary Phase Shift Keying (QPSK), Quadrature Amplitude Modulation (16 QAM, 64 QAM, **256 QAM**)	Subcarrier modulations: Binary Phase Shift Keying (BPSK), Quaternary Phase Shift Keying (QPSK), Quadrature Amplitude Modulation (16 QAM, 64 QAM, 256 QAM, **1024 QAM**)

Conclusion and Harmonizing Proposal:

Modern WLAN/WIFI uses digital modulation schemes that are difficult to emulate with “simple” pulse modulations.
Thus, the harmonizing proposal is to use PM (1000 Hz, 50 % duty cycle) that is similar to 3G/4G/5G or a 20/40/80 MHz AWGN signal, the latter taking into account that the maximum bandwidth of an AWGN signal currently cannot exceed 100 MHz (technically not possible).

Source: Jaidev Sharma, The Wi-Fi Evolution, White Paper, 2020.03

* **bold** print indicates the highest modulation