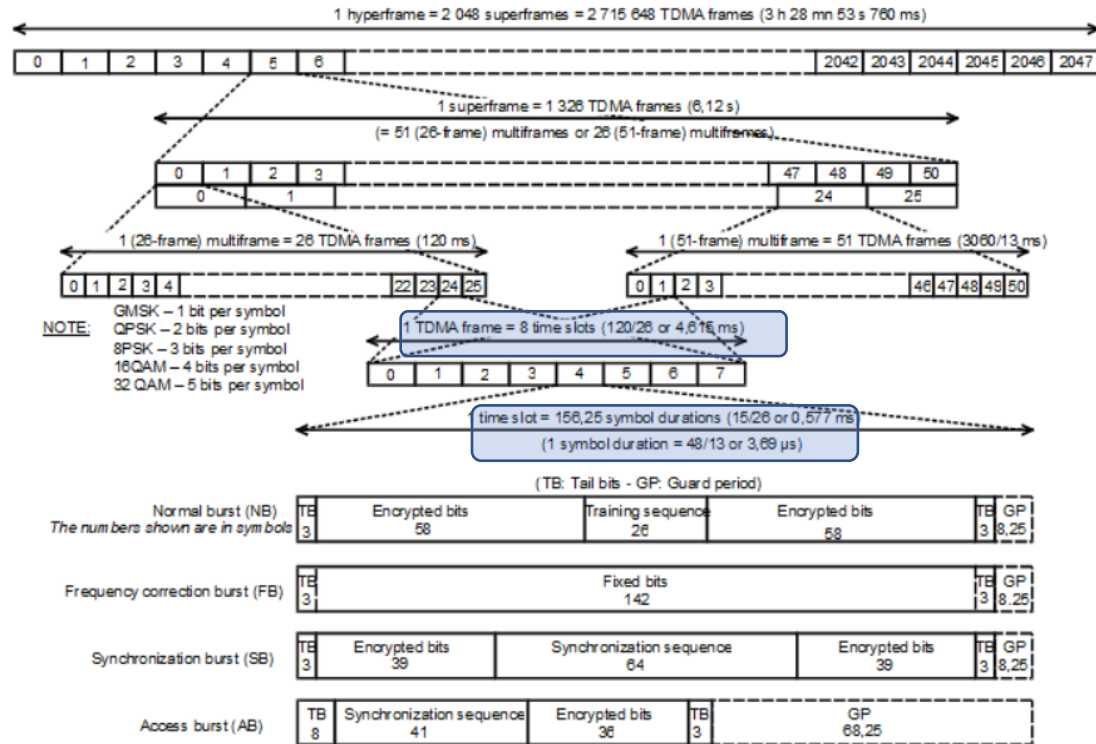


OICA and CLEPA joint  
contribution to  
GRE-90-23 and GRE-90-35

# Rationale for introducing a new pulse modulations

## 2G (GSM) Frame Structure

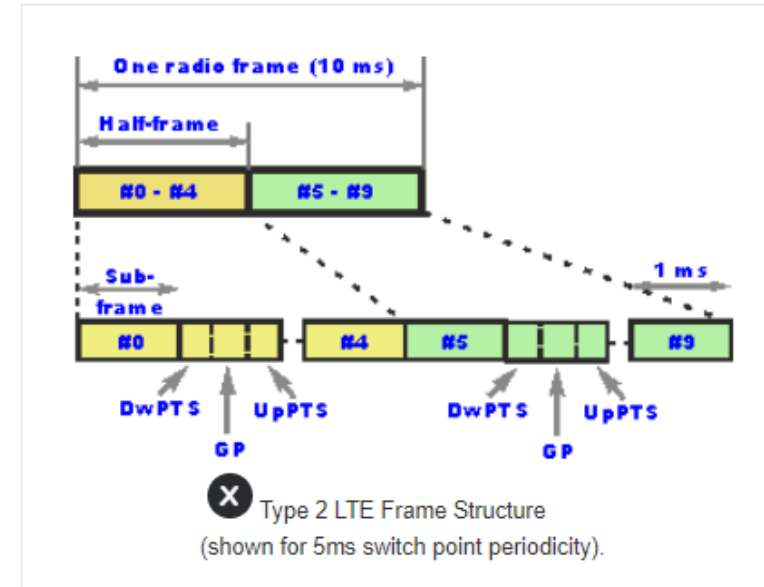


Frame length: 4.16ms = 217Hz  
Slot length: 577μs

This corresponds to PM (217Hz, 577μs)!

Conclusion:  
PM1 (217Hz, 577μs) is suitable to emulate 2G.

## 4G (LTE) Frame Structure Type 2 (TDD)



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

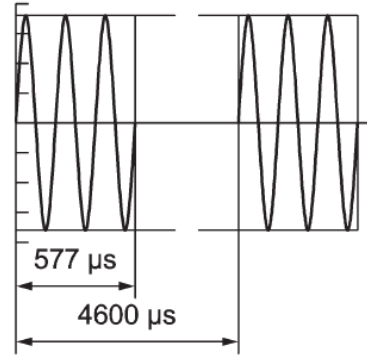
This corresponds to PM (1000 Hz, 10% duty cycle)!

Conclusion: An eligible modulation to emulate LTE is PM3 (1000Hz, 10% duty cycle). In order to consider multiple LTE transceivers transmitting simultaneously, the duty cycle was updated to 50%. The PM with 1000Hz and 50% modulation is also required in MIL-STD-461G.

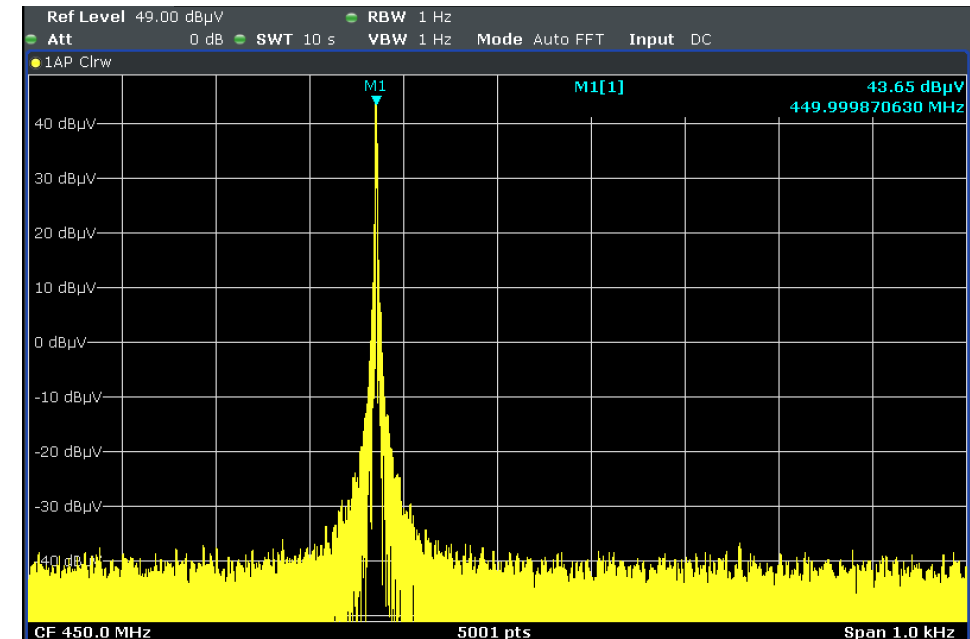
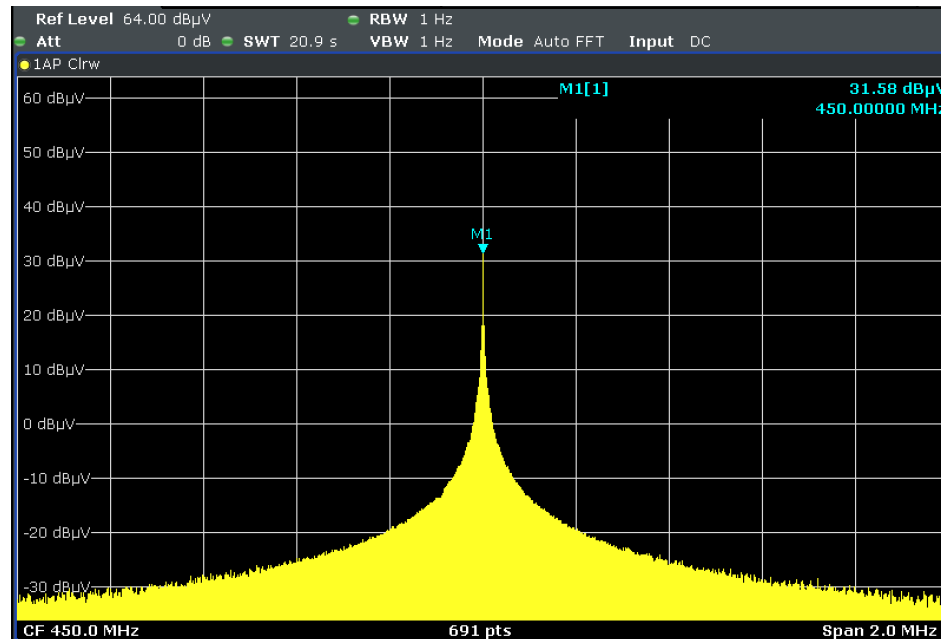
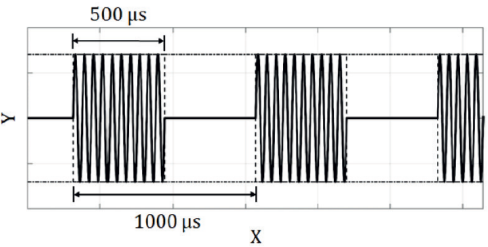
# Envelope Spectrum of PM1 and PM3 in comparison

Signal generator connected to spectrum analyzer, Carrier Frequency: 450 MHz, Level: 50 dB $\mu$ V; RBW: 1 Hz

**PM1:** 217 Hz, 12,5 % duty cycle



**PM3:** 1 kHz, 50% duty cycle



PM3 covers PM1: higher modulation frequency (pulse rate) and higher duty cycle is considered to be more harmful.

# Frequency ranges for state-of-the art cellular applications

## 3GPP TS 36.101 V18.5.0 (2024-03)

Technical Specification

3rd Generation Partnership Project;  
 Technical Specification Group Radio Access Network;  
 Evolved Universal Terrestrial Radio Access (E-UTRA);  
 User Equipment (UE) radio transmission and reception  
 (Release 18)

Release 18

48

3GPP TS 36.101 V18.5.0 (2024-03)

E-UTRA Operating Band	Uplink (UL) operating band BS receive UE transmit		Downlink (DL) operating band BS transmit UE receive		Duplex Mode
	F <sub>UL,low</sub>	F <sub>UL,high</sub>	F <sub>DL,low</sub>	F <sub>DL,high</sub>	
1	1920 MHz	1980 MHz	2110 MHz	2170 MHz	FDD
2	1850 MHz	1910 MHz	1930 MHz	1990 MHz	FDD
3	1710 MHz	1785 MHz	1805 MHz	1880 MHz	FDD
4	1710 MHz	1755 MHz	2110 MHz	2155 MHz	FDD
5	824 MHz	849 MHz	869 MHz	894 MHz	FDD
6 <sup>1</sup>	830 MHz	840 MHz	875 MHz	885 MHz	FDD
7	2500 MHz	2570 MHz	2620 MHz	2690 MHz	FDD
8	880 MHz	915 MHz	925 MHz	960 MHz	FDD
9	1749.9 MHz	1784.9 MHz	1844.9 MHz	1879.9 MHz	FDD
10	1710 MHz	1770 MHz	2110 MHz	2170 MHz	FDD
11	1427.9 MHz	1447.9 MHz	1475.9 MHz	1495.9 MHz	FDD
12	699 MHz	716 MHz	729 MHz	746 MHz	FDD
13	777 MHz	787 MHz	746 MHz	756 MHz	FDD
14	788 MHz	798 MHz	758 MHz	768 MHz	FDD
15	Reserved		Reserved		FDD
16	Reserved		Reserved		FDD
17	704 MHz	716 MHz	734 MHz	746 MHz	FDD
18	815 MHz	830 MHz	860 MHz	875 MHz	FDD
19	830 MHz	845 MHz	875 MHz	890 MHz	FDD
20	832 MHz	862 MHz	791 MHz	821 MHz	FDD
21	1447.9 MHz	1462.9 MHz	1495.9 MHz	1510.9 MHz	FDD
22	3410 MHz	3490 MHz	3510 MHz	3590 MHz	FDD
23 <sup>1</sup>	2000 MHz	2020 MHz	2180 MHz	2200 MHz	FDD
24 <sup>17</sup>	1626.5 MHz	1660.5 MHz	1525 MHz	1559 MHz	FDD
25	1850 MHz	1915 MHz	1930 MHz	1995 MHz	FDD
26	814 MHz	849 MHz	859 MHz	894 MHz	FDD
27	807 MHz	824 MHz	852 MHz	869 MHz	FDD
28	703 MHz	748 MHz	758 MHz	803 MHz	FDD
29			717 MHz	728 MHz	FDD <sup>2</sup>
30 <sup>18</sup>	2305 MHz	2315 MHz	2350 MHz	2360 MHz	FDD
31	452.5 MHz	457.5 MHz	462.5 MHz	467.5 MHz	FDD
32			1452 MHz	1496 MHz	FDD <sup>2</sup>
**					**

Excerpt of 4G (LTE) frequency bands



## 3GPP TS 38.101-1 V18.5.0 (2024-03)

Technical Specification

3rd Generation Partnership Project;  
 Technical Specification Group Radio Access Network;  
 NR;  
 User Equipment (UE) radio transmission and reception;  
 Part 1: Range 1 Standalone  
 (Release 18)

Release 18

35

3GPP TS 38.101-1 V18.5.0 (2024-03)

n1	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	FDD
n2	1850 MHz – 1910 MHz	1930 MHz – 1990 MHz	FDD
n3	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	FDD
n5	824 MHz – 849 MHz	869 MHz – 894 MHz	FDD
n7	2500 MHz – 2570 MHz	2620 MHz – 2690 MHz	FDD
n8	880 MHz – 915 MHz	925 MHz – 960 MHz	FDD
n12	699 MHz – 716 MHz	729 MHz – 746 MHz	FDD
n13	777 MHz – 787 MHz	746 MHz – 756 MHz	FDD
n14	788 MHz – 798 MHz	758 MHz – 768 MHz	FDD
n18	815 MHz – 830 MHz	860 MHz – 875 MHz	FDD
n20	832 MHz – 862 MHz	791 MHz – 821 MHz	FDD
n24 <sup>18</sup>	1626.5 MHz – 1660.5 MHz	1525 MHz – 1559 MHz	FDD
n25	1850 MHz – 1915 MHz	1930 MHz – 1995 MHz	FDD
n26	814 MHz – 849 MHz	859 MHz – 894 MHz	FDD
n28	703 MHz – 748 MHz	758 MHz – 803 MHz	FDD
n29	N/A	717 MHz – 728 MHz	SDL <sup>19</sup>
n30 <sup>1</sup>	2305 MHz – 2315 MHz	2350 MHz – 2360 MHz	FDD
n31	452.5 MHz – 457.5 MHz	462.5 MHz – 467.5 MHz	FDD
n34	2010 MHz – 2025 MHz	2010 MHz – 2025 MHz	TDD
n38 <sup>19</sup>	2570 MHz – 2620 MHz	2570 MHz – 2620 MHz	TDD
n39	1880 MHz – 1920 MHz	1880 MHz – 1920 MHz	TDD
n40	2300 MHz – 2400 MHz	2300 MHz – 2400 MHz	TDD
n41	2496 MHz – 2690 MHz	2496 MHz – 2690 MHz	TDD
n46	5150 MHz – 5925 MHz	5150 MHz – 5925 MHz	TDD <sup>13</sup>
n47 <sup>11</sup>	5855 MHz – 5925 MHz	5855 MHz – 5925 MHz	TDD
n48	3550 MHz – 3700 MHz	3550 MHz – 3700 MHz	TDD
n50	1432 MHz – 1517 MHz	1432 MHz – 1517 MHz	TDD <sup>1</sup>
n51	1427 MHz – 1432 MHz	1427 MHz – 1432 MHz	TDD
n53	2483.5 MHz – 2495 MHz	2483.5 MHz – 2495 MHz	TDD
n54	1670 MHz – 1675 MHz	1670 MHz – 1675 MHz	TDD
n65	1920 MHz – 2010 MHz	2110 MHz – 2200 MHz	FDD <sup>4</sup>
n66	1710 MHz – 1780 MHz	2110 MHz – 2200 MHz	FDD
n67	N/A	738 MHz – 758 MHz	SDL <sup>19</sup>
n70	1695 MHz – 1710 MHz	1995 MHz – 2020 MHz	FDD
n71	663 MHz – 698 MHz	617 MHz – 652 MHz	FDD
n72	451 MHz – 456 MHz	461 MHz – 466 MHz	FDD
n74	1427 MHz – 1470 MHz	1475 MHz – 1518 MHz	FDD
n75	N/A	1432 MHz – 1517 MHz	SDL <sup>19</sup>
n76	N/A	1427 MHz – 1432 MHz	SDL <sup>19</sup>
n77 <sup>12</sup>	3300 MHz – 4200 MHz	3300 MHz – 4200 MHz	TDD
n78	3300 MHz – 3800 MHz	3300 MHz – 3800 MHz	TDD
n79 <sup>17</sup>	4400 MHz – 5000 MHz	4400 MHz – 5000 MHz	TDD
n80	1710 MHz – 1785 MHz	N/A	SUL
n81	880 MHz – 915 MHz	N/A	SUL

Excerpt of 5G NR FR1 frequency bands



Source: [Specification # 36.101 \(3gpp.org\)](https://www.3gpp.org/specifications/specification.aspx?spec_id=7311)

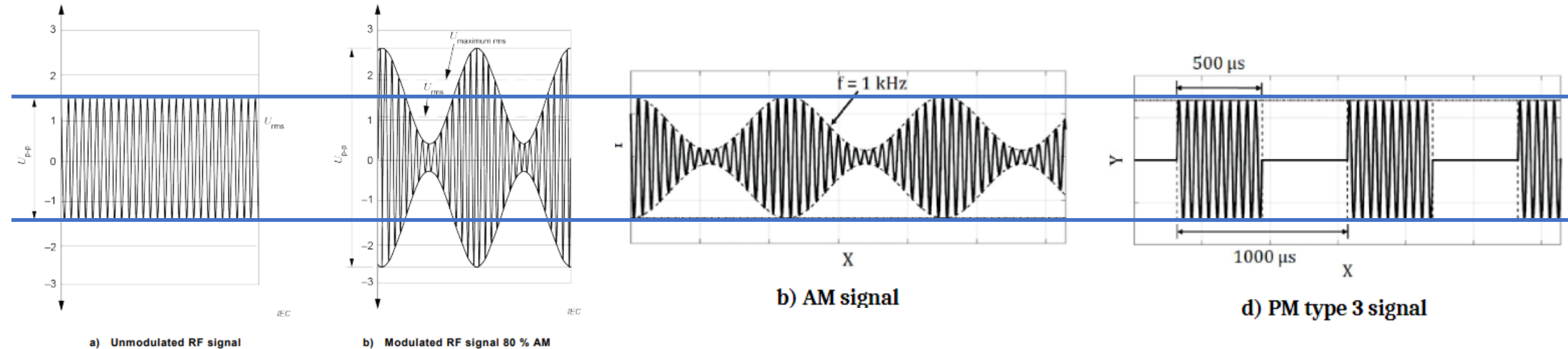
Source: [Specification # 38.101-1 \(3gpp.org\)](https://www.3gpp.org/specifications/specification.aspx?spec_id=7312)

# AM Modulation: Upward vs. downward modulation

AM upward modulation per IEC 61000-4-3:2020

AM downward modulation per ISO 11451-1:2015 & ISO 11452-1:2015

PM3 per ISO 11451-1 DIS (N3346) and 11452-1 DIS (N3342)



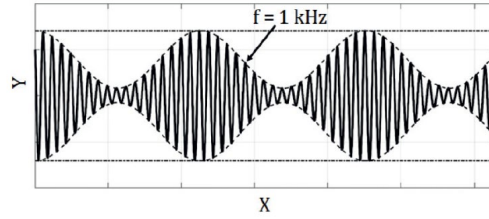
Peak conservation in ISO 11451-1 and 11452-1 ensures that the maximum amplitude level of AM does not exceed the maximum CW level while PM corresponds to a pulsed (i.e. on-off) CW signal.

In contrast to AM, PM additionally emulates switching characteristics of a digital modulated signal.

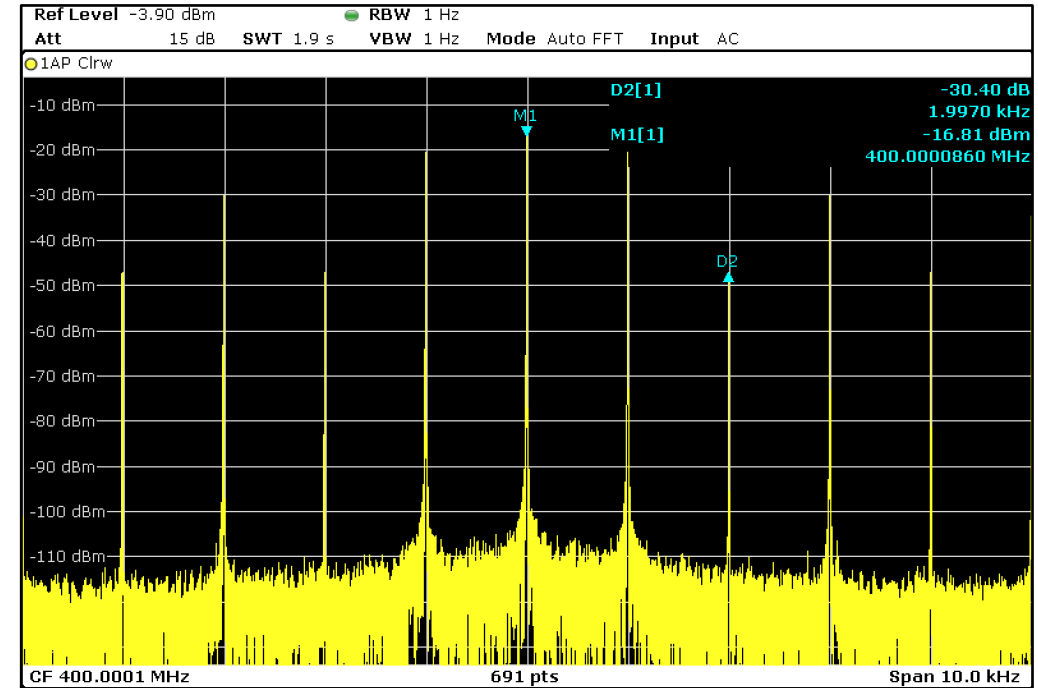
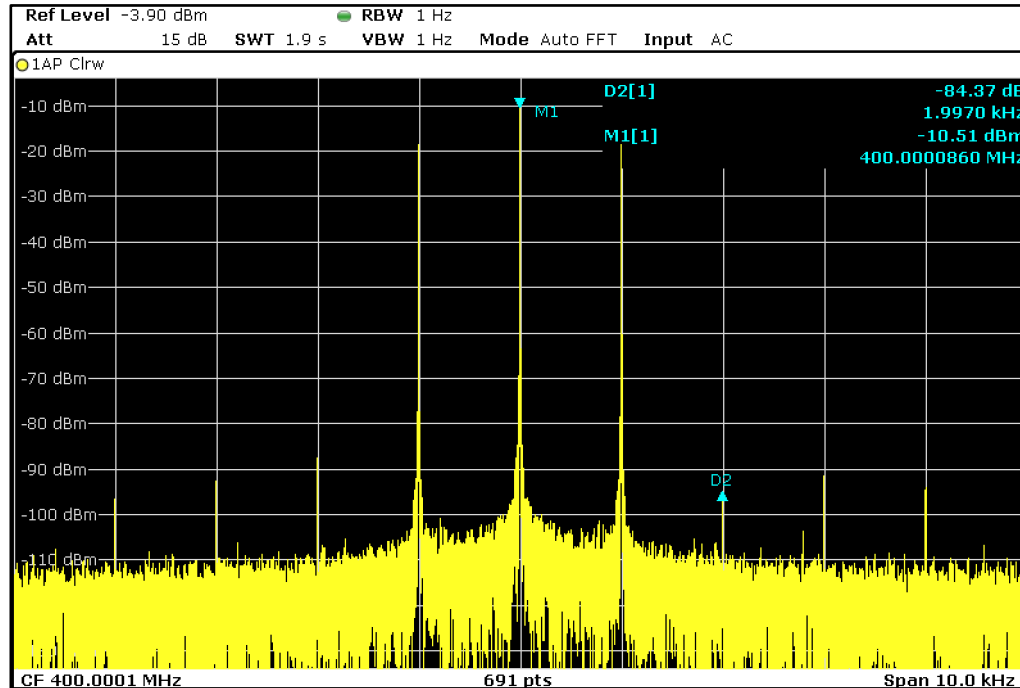
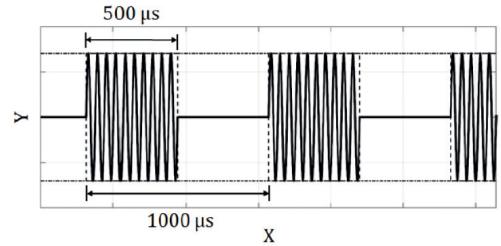
# Spectrum of AM and PM3 in comparison

Signal generator connected to spectrum analyzer, Carrier Frequency: 400 MHz, Level: -10 dBm; RBW: 1 Hz

**AM:** 1 kHz, 80% depth



**PM3:** 1 kHz, 50% duty cycle



Equal modulation frequency for AM and PM3: distance between two spectral lines is 1 kHz for both modulations.

# Summary of AM use

## Communication applications:

- PM3 was introduced at 380 MHz to cover TETRA, 4G, 5G, WIFI

## Maritime<sup>1)</sup> applications:

- 1,6 – 27,5 MHz (J3E: single sideband without carrier)

## Railway<sup>2)</sup> applications:

- Old train station control systems might still use AM
- Train radio: FM or TETRA

## Aviation<sup>3)</sup> applications:

- Frequency range for civil applications: 108 - 137 MHz (Aircraft communications radio)
- Frequency range for military applications: 225 - 400 MHz (Aircraft communications radio)

## Amateur Radio<sup>4)</sup> :

- Focus on frequency bands with PRIMARY status: 1,8 – 450 MHz (and 24 – 250 GHz)
- No practical use reported in the 70 cm (420 – 450 MHz) band: highest frequency << 450 MHz

## Infotainment applications<sup>5)</sup>:

- Radio broadcasting: LF: 0,1485 – 0,2835 MHz / MF: 0,5265 – 1,607 MHz / HF: 3,9 – 26,1 MHz
- Analog television: 47 – 838 MHz; Reference document does not provide detailed information on modulation; Analog television outdated – digital television services apply other modulations (typically OFDM, carriers with QAM);
- Spectrum comparison of AM and PM3 shows similarities between both modulations

1) Information provided by Bundesamt für Seeschifffahrt und Hydrographie (The BSH is a higher federal authority within the portfolio of the Federal Ministry for Digital and Transport.)

2) Source: German component manufacturer for trains

3) Sources: [Complete List Of Airband Frequencies.. | Skyscanworld.com](#), [The basics of air band radios \(buytwowayradios.com\)](#), [Common Military \(United States\) Scanner Frequencies and Radio Frequency Reference \(radioreference.com\)](#)

4) Source: International Amateur Radio Union (IARU), ITU - Amateur and Amateur-satellite Service Spectrum

5) Source: [Radio Services Database](#) CISPR/TR 31 V4 => reference document: Recommendation ITU-R BT.417-5

# Recap: OICA and CLEPA proposal

As given in GRE-90-23 and GRE-90-35:

**The test signal modulation shall be:**

- a) **AM (amplitude modulation), with 1 kHz modulation and 80 per cent modulation depth in the 20 to ~~800~~ 400 MHz frequency range; and**
- b) **PM2 (pulse modulation type 2), Ton 3  $\mu$ s, period 3,333  $\mu$ s in the 2,700 to 3,100 MHz frequency range; and**
- c) **PM3 (pulse modulation type 3), Ton 500  $\mu$ s, period 1,000  $\mu$ s in the ~~800~~ 380 to 2,700 MHz and the 3,100 to 6,000 MHz frequency ranges.**

**Summary: Extend the use of PM3 to start from 380 MHz instead of 800. Limit use of AM to 400 MHz**

As given in ISO/2<sup>nd</sup> DIS 11451-1 (N3346) and ISO/2<sup>nd</sup> DIS 11452-1 (N3342):

- AM: 10 kHz to 400 MHz;
- PM type 2: 2,7 GHz to 3,1 GHz;
- PM type 3: 380 MHz to 2,7 GHz and 3,1 GHz to 18 GHz.