White Paper

5G TDD synchronisation in the Caribbean region in the 3400-3800 MHz band: a new challenge

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Contents

5G TDD rollout: why is it a challenge?

The purpose of this white paper is to describe the issues being faced in the Caribbean region with the imminent introduction of 5G TDD technology in the 3400-3800 MHz band. In contrast to the FDD access method, TDD systems introduce an additional degree of freedom, which obliges parties to agree, as far as possible, the uplink/downlink ratio in order to avoid coexistence issues. This paper presents these issues and proposes solutions to minimise interference while protecting the existing systems.

In the Caribbean region, from the north with the British Virgin Islands down to the south with Trinidad and Tobago there are many islands that are geographically close. The islands of the French overseas territories are located in the middle of this region. To ensure 5G networks' compatibility with neighbouring islands, it is necessary for all parties involved to carefully choose the 5G TDD frame structure: both the uplink/downlink ratio and the order of TDD time slots (up/down).

What are the problems?

In order to do so, some 5G transmitters were set up in coastal areas of an island A to determine the field strength level produced at the coastline of an island B with a transmit power of 68 dBm/5 MHz and a height of 25 m (transmitters are represented in green in **Figure-1** below). ECC Recommendation 15(01) stipulates that, for unsynchronised systems, a field strength value of 0 dBµV/m/5 MHz must be respected to avoid interference between islands. However, in this study, this constraint was relaxed to 32 dBµV/m/5 MHz to allow room for improvement that could be discussed at CEPT level.

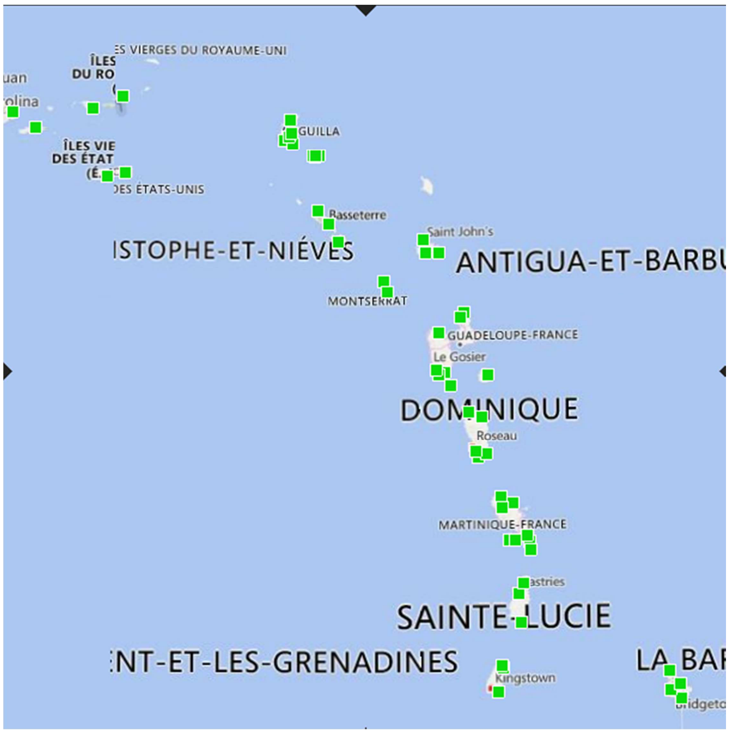

Figure-1: study area

A field strength value over 32 dBµV/m/5 MHz shows that islands A and B are linked, and could negatively influence each other, so therefore careful choice of 5G frame structure needs to be made.

Furthermore, as many islands have existing services or systems (FWA, Wimax, PMP450, LTE, etc.) to protect, a set of compatible frame structures must be determined and this is what this study aims to verify.

ANFR's analysis

The propagation model used for this study is the ITU-R model P.1546, set at 10% of the time and 50% of the locations with a DTM of 50 m without clutter.

Figure-2 shows that transmitters located in Saint-Martin / Sint-Marteen (in green) have an impact as far as the **British Virgin Islands** to the north and as far as to **Saba and Sint-Eustatius (BES), Saint Kitts and Nevis (KNA), Monserrat, Antigua and Guadeloupe** to the south.

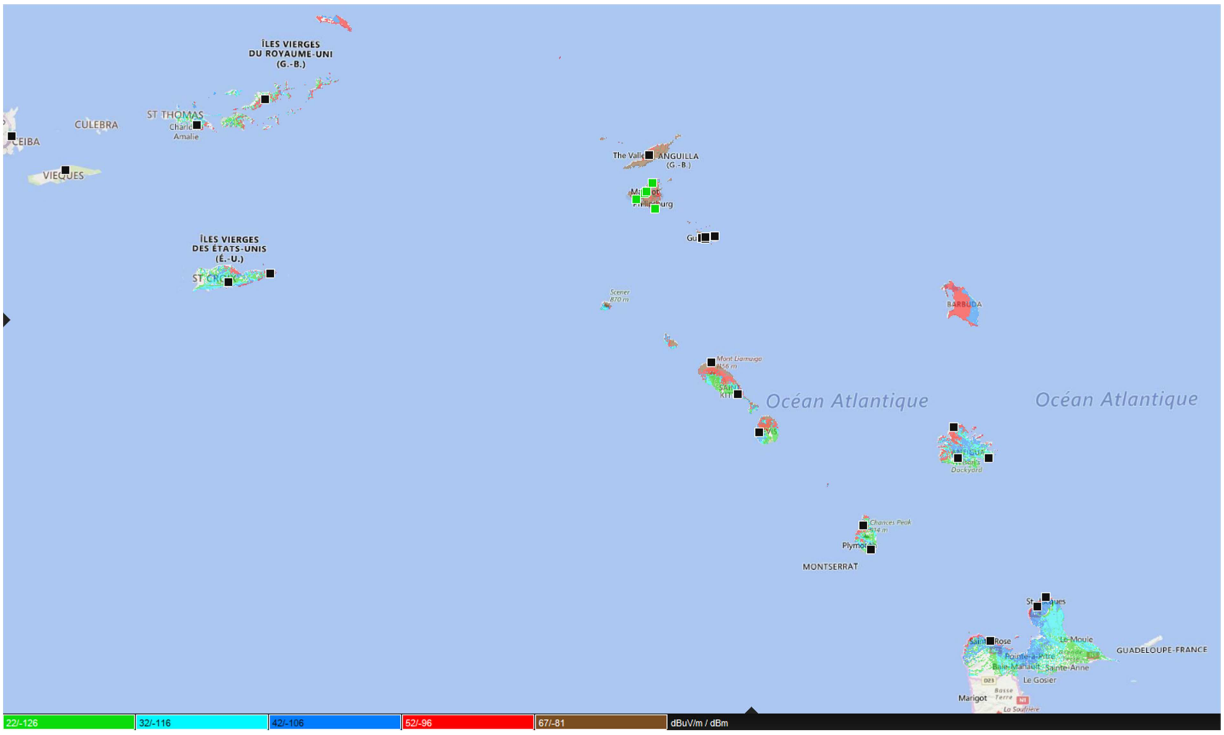

Figure-2: transmitters located in Saint-Martin/ Sint-Maarten

Figure-3 shows that transmitters located in **Martinique** have an impact on **Dominica** and **Guadeloupe** to the north and as far as **Barbados** including **Saint Lucia** and **Saint Vincent and Grenadines** to the south.

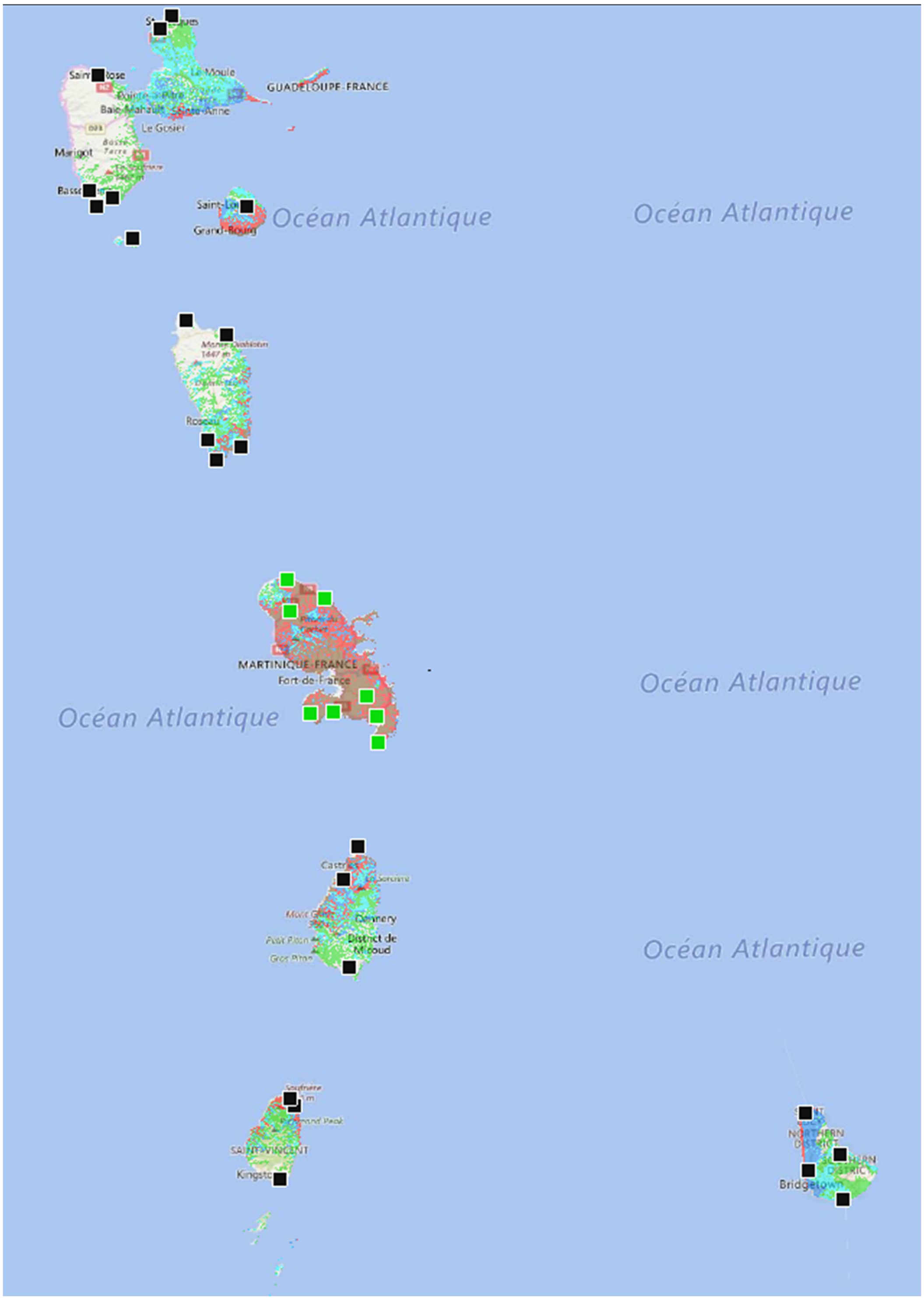

Figure-3: transmitters located in Martinique

Conclusion-1: There is interaction between the British Virgin Islands in the north and as far as Trinidad and Tobago in the south by virtue of a domino effect with the islands in-between (even if such interaction was only studied up to Barbados). A pure 5G frame structure - such as DDDSUDDDSU (5 ms), where S represents a slot with symbols in DL and UL - cannot guarantee compatibility with existing systems (e.g. Wimax, LTE, etc.). This solution should ideally be excluded in the Caribbean region.

Conclusion-2: Even if the same 5G frame structure is used between two islands (e.g. Saint Martin and Guadeloupe in France), the guard period must be assessed carefully to compensate the propagation delay between islands and ensure continuing compatibility. To illustrate this, for a distance of approximately 250 km between St Martin and Guadeloupe and 130 km between Guadeloupe and Martinique, the 5G frame would require a guard time of 834 µs and 434 µs respectively in order not to cause interference (180 km for BVI corresponds to 600 µs).

What are the solutions to protect the existing systems (Wimax, LTE, etc.)?

As Wimax and LTE/5G frames are by nature different and not aligned, taking Wimax or other systems into account makes the problem of compatibility between countries more complex, because it is necessary not only to synchronize the networks with the same clock but also to agree (via a time offset) on the instant t (time stamp) which corresponds to the start of the downlink transmission.

The table below (**Table-1**), taken from ECC Report 216, lists the different Wimax and LTE compatible configurations (in green) taking into account the time stamp assumption mentioned above.

				LTE U-D Configuration		1									2								
					"S" frame	0	1	2	3	4	5	6	7	8	0	1	2	3	4	5	6	7	8
	Ratio DL					44,3%	52,9%	54,3%	55,7%	57,1%	44,3%	52,9%	54,3%	55,7%	64,3%	72,9%	74,3%	75,7%	77,1%	64,3%	72,9%	74,3%	75,7%
		DL length (µs)				2215	2643	2715	2786	2857	2215	2643	2715	2786	3215	3643	3715	3786	3857	3215	3643	3715	3786
			TTG / GP (µs)			714	285	214	143	71	643	214	143	71	714	285	214	143	71	643	214	143	71
				UL length (µs)		2071	2071	2071	2071	2071	2143	2143	2143	2143	1071	1071	1071	1071	1071	1143	1143	1143	1143
					UL start (µs)	2929	2929	2929	2929	2929	2857	2857	2857	2857	3929	3929	3929	3929	3929	3857	3857	3857	3857
Config. WiMAX																							
10MHz 35:12	74,5%	3600	106	1234	3706	-671	-671	-671	-671	-671	-743	-743	-743	-743	329	62	-9	-80	-152	257	62	-9	-80
10MHz 34:13	72,3%	3497	106	1337	3603	-568	-568	-568	-568	-568	-640	-640	-640	-640	388	-40	-112	-183	-254	360	-40	-112	-183
10MHz 33:14	70,2%	3394	106	1440	3500	-466	-466	-466	-466	-466	-537	-537	-537	-537	285	-143	-215	-286	-357	285	-143	-215	-286
10MHz 32:15	68,1%	3291	106	1543	3397	-363	-363	-363	-363	-363	-434	-434	-434	-434	183	-246	-317	-389	-460	183	-246	-317	-389
10MHz 31:16	66,0%	3189	106	1646	3294	-260	-260	-260	-260	-260	-331	-331	-331	-331	80	-349	-420	-492	-563	80	-349	-420	-492
10MHz 30:17	63,8%	3086	106	1749	3191	-157	-157	-157	-157	-157	-228	-228	-228	-228	-23	-452	-523	-595	-666	-23	-452	-523	-595
10MHz 29:18	61,7%	2983	106	1851	3089	-54	-54	-54	-54	-54	-126	-126	-126	-126	-126	-555	-626	-697	-769	-126	-555	-626	-697
10MHz 28:19	59,6%	2880	106	1954	2986	49	49	49	49	49	-23	-23	-23	-23	-229	-658	-729	-800	-872	-229	-658	-729	-800
10MHz 27:20	57,4%	2777	106	2057	2883	152	152	152	97	26	80	80	80	80	-332	-760	-832	-903	-974	-332	-760	-832	-903
10MHz 26:21	55,3%	2674	106	2160	2780	254	137	65	-6	-77	183	137	65	-6	-435	-863	-935	-1006	-1077	-435	-863	-935	-1006
8,75MHz 30:12	71,4%	3456	87	1382	3543	-527	-527	-527	-527	-527	-599	-599	-599	-599	329	-100	-171	-243	-314	329	-100	-171	-243
8,75MHz 29:13	69,0%	3341	87	1498	3428	-412	-412	-412	-412	-412	-484	-484	-484	-484	213	-215	-287	-358	-429	213	-215	-287	-358
8,75MHz 28:14	66,7%	3226	87	1613	3313	-297	-297	-297	-297	-297	-368	-368	-368	-368	98	-330	-402	-473	-544	98	-330	-402	-473
8,75MHz 27:15	64,3%	3110	87	1728	3198	-182	-182	-182	-182	-182	-253	-253	-253	-253	-17	-446	-517	-588	-660	-17	-446	-517	-588
8,75MHz 26:16	61,9%	2995	87	1843	3082	-67	-67	-67	-67	-67	-138	-138	-138	-138	-132	-561	-632	-704	-775	-132	-561	-632	-704
8,75MHz 25:17	59,5%	2880	87	1958	2967	49	49	49	49	49	-23	-23	-23	-23	-247	-676	-747	-819	-890	-247	-676	-747	-819
8,75MHz 24:18	57,1%	2765	87	2074	2852	164	164	137	66	-5	92	92	92	66	-363	-791	-863	-934	-1005	-363	-791	-863	-934
7MHz 24:9	72,7%	3456	188	1296	3644	-527	-527	-527	-527	-527	-599	-599	-599	-599	429	1	-71	-142	-213	401	1	-71	-142
7MHz 23:10	69,7%	3312	188	1440	3500	-383	-383	-383	-383	-383	-455	-455	-455	-455	285	-143	-215	-286	-357	285	-143	-215	-286
7MHz 22:11	66,7%	3168	188	1584	3356	-239	-239	-239	-239	-239	-311	-311	-311	-311	141	-287	-359	-430	-501	141	-287	-359	-430
7MHz 21:12	63,6%	3024	188	1728	3212	-95	-95	-95	-95	-95	-167	-167	-167	-167	-3	-431	-503	-574	-645	-3	-431	-503	-574
7MHz 20:13	60,6%	2880	188	1872	3068	49	49	49	49	49	-23	-23	-23	-23	-147	-575	-647	-718	-789	-147	-575	-647	-718
7MHz 19:14	57,6%	2736	188	2016	2924	193	193	193	138	67	121	121	121	121	-291	-719	-791	-862	-933	-291	-719	-791	-862
7MHz 18:15	54,5%	2592	188	2160	2780	337	137	65	-6	-77	265	137	65	-6	-435	-863	-935	-1006	-1077	-435	-863	-935	-1006

Table-1 : Wimax /LTE Compatibility (from ECC Rapport 216)

The LTE configuration adopted in mainland France, Configuration #2, Special Subframe "S" #7 with a Downlink ratio of 74.3% is not compatible with Wimax and offers a guard period of 143 µs, which is, moreover, insufficient to compensate the propagation delay of 434 µs, 600 µs or 834 µs mentioned previously due to interactions between islands.

On the other hand, Configuration #2, Special Subframe "S" #0 with a Downlink ratio of 64.3% is compatible with Wimax and offers a guard period of 714 µs, which eliminates most of the problems linked to the inter-island propagation delay. Note also that this configuration is 100% compatible with Configuration #2, Special Subframe "S" #7, which means that isolated sites (e.g. in a valley) not creating interference can be configured with a downlink ratio of 74.3%.

Conclusion-3: the compatibility of the 5G/LTE and Wimax networks can be achieved as a result of synchronising the different networks: same clock and same start of the downlink transmission via the appropriate time offset.

Conclusion-4: LTE Configuration #2, Special Subframe "S" #0 (3 DL symbols: 10 GP symbols: 1 UL symbol) with a Downlink ratio of 64.3% is the most LTE compatible frame structure with Wimax and offers a guard period of 714 µs, which eliminates most of the problems linked to the inter-island propagation delay. This configuration corresponds to the following LTE frame structure DSUDD (5 ms) with an offset 3 ms (to take into account Conclusion-3) which corresponds to the **LTE frame structure DDDSU** (5ms) in the end. The corresponding **5G frame structure** with a carrier spacing of 30 kHz is DDDDDDS$_1$S$_2$UU (5 ms) including the 3 ms offset, with S$_1$ = (6 DL symbols, 8 GP symbols, 0 UL symbol) and S$_2$ = (0 DL symbol, 12 GP symbols, 2 UL symbols) corresponding, respectively, to the 3GPP Slot Format 18 and Slot Format 9.

Conclusion-5: Inside a country and in order to improve the downlink throughput, LTE/5G heterogeneous networks can be set up through the usage of LTE Configuration #2, Special Subframe "S" #7 (10 DL symbols: 2 GP symbols: 2 UL symbols), with a Downlink ratio of 74.3%. This configuration corresponds to the following LTE frame structure DSUDD (5 ms) with an offset 3 ms (to take into account Conclusion-3) which corresponds to the **LTE frame structure DDDSU** (5ms) in the end. The corresponding **5G frame structure** with a carrier spacing of 30 kHz is DDDDDDDS$_1$UU (5 ms) including the 3 ms offset, with S$_1$ = (6 DL symbols, 4 GP symbols, 4 UL symbol) corresponding to the 3GPP Slot Format 44. This solution remains 100% compatible with LTE Configuration #2, Special Subframe "S" #0 (with the 3ms offset).

Conclusion

The simulations carried out support the need to identify a unique frame structure in the Caribbean region to avoid inter-island interference from north to south (local deviation could be allowed when isolation is respected with some obstacles, e.g. a valley).

The proximity of existing systems (WiMAX, LTE, etc.) requires the use of an LTE/Wimax compatible 5G frame structure.

The need to withstand propagation times between 434 µs and 834 µs and to coexist with TDD systems such as Wimax (whose exact characteristics are still unknown) points to the promotion of the use of the following frames with a 64.3% downlink ratio:

- In LTE, the frame structure configuration #2, **DDDSU** (3GPP frame structure DSUDD + an offset of $t0_{3GPP}$ +3ms) with the **Special Subframe #0** (3 DL: 10 GP: 1 UL), GP = 714 µs
- In 5G (scs = 30 kHz), the frame structure **DDDDDDS$_1$S$_2$UU** (3GPP frame structure DD S_1S_2UUDDDD + an offset $t0_{3GPP}$ +3ms) with **S_1 = (6 DL, 8 GP, 0 UL) and S_2 = (0 DL, 12 GP, 2 UL)** corresponding respectively to the 3GPP Slot Format 18 and Slot Format 9.

Bearing in mind that Special Subframes #0 and #7 are compatible with each other, for isolated sites a heterogeneous network configuration still possible by introducing the Special Subframe #7 to improve the downlink performances (74.3%):

- In LTE, the frame structure configuration #2, **DDDSU** with the **Special Subframe #7** (10 DL: 2 GP: 2UL), here the instant t corresponds to the start of the downlink transmission with the 3 ms offset implemented.

- In 5G (scs = 30 kHz), the frame structure **DDDDDDDSUU** with the slot “S” **Format 44 (6 DL: 4GP: 4UL)**, here the instant t corresponds to the start of the downlink transmission with the 3 ms offset implemented.

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