Guidance on FIC generation for high service count ensembles

Introduction

As the market of DAB digital radio services diversifies, use cases for ensemble operators are getting more complex. The existing requirements and specifications have been sufficient to address traditional ensemble configurations. However, deployment of ensembles with increasing service count world-wide has shown that the rules of FIC repetition rates leave room for interpretation.

This document addresses best practice in FIC scheduling when the number of services in an ensemble is more than 20.

Normative References

[1] ETSI EN 300 401: Radio Broadcasting Systems; Digital Audio Broadcasting (DAB) to mobile, portable and fixed receivers, V2.1.1 (2017-01)

[2] ETSI TS 103 176: Digital Audio Broadcasting (DAB); Rules of implementation; Service information features; V2.4.1 (2020-08)

Synopsis of specifications

The following paragraphs quote relevant existing requirements and specifications. It is recommended to read EN 300 401 clause 6.1 [1] and TS 103 176 clause 4 [2] in their entirety for context. TS 103 176 clause 4 has a detailed discussion of FIC signalling and FIG repetition rates. TS 103 176 Annex F provides an example FIC coding for an ensemble with 20 services.

MCI Rule

> EN 300 401 clause 6.1: “The complete MCI for one configuration shall normally be signalled in a 96ms period; the exceptions are that the FIG 0/8 for primary service components containing data applications and for data secondary service components, and the FIG 0/13 may be signalled at a slower rate but not less frequently than once per second. When the slower rate is used, the FIG 0/8 and FIG 0/13 for the same service component should be signalled in the FIBs corresponding to the same CIF.”

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Reconfigurations

EN 300 401 clause 6.1: “During the six second period of the reconfiguration, the MCI that describes the next configuration (see clause 6.5) shall be signalled within two consecutive 96ms periods, and during this period the complete current configuration need only be signalled once. For the MCI signalled at the slower rate, that is FIG 0/8 and FIG 0/13 for data applications, both the current and the next configuration shall be signalled within the one second repetition period.”

Nominal repetition rates for SI

TS 103 176 clause 4: “The nominal repetition rate for SI FIGs is once per second. This rate applies to FIG 0/5, FIG 0/9, FIG 0/10, FIG 0/17, FIG 0/18, FIG 0/20, FIG 0/25, FIG 1/x and FIG 2/x.”

Higher service count consideration

TS 103 176 clause 4: “The signalling in the FIC of both MCI and SI can achieve the nominal repetition rates for ensembles with up to 20 DAB+ audio services, each carrying a SlideShow in PAD, and with additional SI for date and time, language, programme type, service following and announcements. An example of the FIC coding for such an ensemble is given in annex F. However, due to the fixed capacity of the FIC, when a greater number of service components is present, the signalling rates will be lower. It is recommended that of the 12 FIBs available in each 96 ms period, a maximum of 10 are allocated to delivering the MCI and labels, with the remaining FIBs allocated to SI.”

Worst case FIG rates

TS 103 176 clause 4: “The configuration of the ensemble and the SI features supported determine the actual repetition rates signalled for each FIG, and these shall not fall below one third of the nominal rates defined in ETSI EN 300 401 [1] and table 1 of the present document.”

Rule of thumb

TS 103 176 clause 4: “A reasonable rule of thumb is to expect the repetition rates to decline to be about half of the nominal rates as the number of service components rises to around 40, and to further decline to be about one third of the nominal rates when about 60 service components are present in an ensemble. The number of services in the ensemble is provided by FIG 0/7, which can be used to verify when the complete MCI has been received. The total number of service components can then be determined from FIG 0/2 to give an indication of the likely repetition rates.”

Summary of key requirements

FIC information can be sorted into four groups by FIG repetition rate requirements.

(A) MCI has a nominal repetition rate of 96 ms. That is all information should be repeat every transmission frame. This includes FIG 0/1, FIG 0/2 and if present FIG 0/3, FIG 0/4, FIG 0/8,

FIG 0/13 and FIG 0/14. FIG 0/8 and FIG 0/13 may be sent at rate (B). FIG 0/0 and FIG 0/7 are defined as the first FIGs in every transmission frame.

(B) SI with a nominal repetition rate of 1 second: all information should be repeat every second. This includes among others all FIG 1 and all FIG 2 labels (ensemble label, service label, service component label, X-PAD user application label), FIG 0/5, FIG 0/17 and FIG 0/18.

(B+) SI with a burst requirement to be sent 10 times every second for 2 or 5 seconds. This includes announcement switching FIGs and change of database signalling for some FIG type 0 extensions.

(C) SI with a nominal repetition rate of 'all information within 2 minutes'. This applies to FIG 0/6, FIG0/21 and FIG0/24.

All repetition rates are 'nominal', as various situations may lead to slower or faster repetition rates. However, for SI at rate class (B+) the rates should not be reduced as the functions are for various timing critical signalling purposes, and for SI at rate class (B) it is generally recommended to not exceed nominal rates, i.e., not to fill FIC spare capacity, unless used for service labels or filled with padding.

NOTE: while the DAB standards define requirements for the repetition rate for FIGs, they do not consider variation or jitter. In practise, variation of the repetition rate has been seen to lead to poor acquisition of service lists in receivers. Therefore, both repetition cycle average time *and* variation must be taken care of in FIC generation.

The lowest permissible repetition in any situation for all FIGs is 'three times nominal', meaning 288 ms for rate class (A) and 3 seconds for rate class (B). However, the specifications provide no specific guidance on how to deal with FIG scheduling.

User experience considerations

Ensemble acquisition time

When a receiver first acquires an ensemble, it builds the complete service list for user presentation. At that time, it needs to wait for all information to be received. In practise this wait time is the lower bound to receive all (service and service component) labels. The receiver derives the number of services and service components from the FIG 0/2 information (with help from FIG 0/7 in the case of DAB version 2.1.1 ensembles), but the label cycle time (FIG 1 and/or FIG 2) represents the critical time constant.

In order to avoid excessive scan times when acquiring the service list, receiver manufacturers use a time-out to limit the waiting time for labels. If the time-out is reached before all labels have been received, the receiver aborts the data collection for the tuned ensemble and tunes to the next ensemble in the spectrum and the service list is incomplete. Typically, services are omitted at random, depending on the moment of scanning.

An incomplete service list must be considered a failure situation from both the broadcaster and user perspective. Short spectrum scan times contribute to listener convenience. Ensembles must seek to avoid excessive service label repetition cycles.

Time to audio

When tuning to an ensemble that has been tuned before and the service list has been acquired and is available in memory, the receiver still needs to acquire core MCI (FIG 0/1 and FIG 0/2) to understand the organisation of the MSC and start the decoding of an audio sub-channel.

The time-to-audio in a receiver is composed of the MCI reception latency, the audio frame assembly time and receiver specific factors such as audio decoder and buffer fill delays. Of these only the MCI cycle time is ensemble dependent.

As time-to-audio in DAB receivers is typically in the 1 second order, a variation of 100 to 300 ms in MCI latency (depending on the number of service components) does not dominate the user experience. Specifically, MCI latency at 300 ms does not expose a failure situation: it will often not even be noticeable by the listener at all.

FIG multiplexing considerations

The principles used when inserting FIGs into FIBs depend on the data to be inserted for general guideline considerations. Two aspects can be identified as figures of merit.

- The **load factor** of the FIC is the ratio of “FIG bytes used” to “total FIB bytes”. Due to FIG sizes most often not summing up to a full FIB (30 bytes), the load factor in real-world ensembles lies well below 100%. That is the capacity of the FIC that can be utilised for signalling.
- The **overhead** of FIG insertion is the ratio of header bytes to data bytes used per FIG. In particular, core MCI FIGs are structured by service fields, so that information for several services can be carried in one FIG. Generally, the ratio of header bytes to data bytes per FIG will be lower if larger FIGs are inserted. However, filling a FIB by including smaller (single service field) FIGs will contribute to a higher load factor.

Maximising the load factor, while at the same time minimising the overhead is a complex problem for which no optimal solution exists. Increasing the load factor at the expense of increasing the overhead of FIG insertion may not increase the throughput of information.

On-air ensembles typically achieve a FIC load factor of between 75% and 90%.

Guideline

General

This guideline uses the term service to mean a service consisting of a single audio service component with PAD; for more complex service structures with multiple service components, the guidance can be interpreted as a service meaning a labelled service component.

The main principle for FIG prioritisation is that with increasing service count, most FIG types should be delayed by equal factors relative to the nominal repetition cycle times.

High volume FIGs

As the user experience considerations have shown, two groups of FIC information are most critical:

- **Core MCI**: FIG 0/1 and FIG 0/2 represent the most critical metadata. The information occupies the bulk of the FIC and is most critical in terms of repetition rate. However, with increasing number of services in an ensemble, the capacity occupied by core MCI must be limited to leave enough capacity for other data features.
- **Labels**: The repetition cycle of labels is key for the ensemble acquisition time and therefore a critical parameter with direct visibility to the listener. With an increasing number of services, labels must be inserted into the FIC at a high enough rate to not exceed the maximum allowable cycle time.

Calculations of FIC throughput and capacity show that repetition for core MCI and labels must be scaled with the number of services when the service count exceeds 20, as given in table 1.

FIG type	FIC share	Recommendation
FIG 0/1, FIG 0/2	50% -- 180 bytes/96ms	Ensembles should maintain average FIC share of 50%.
FIG 1/1, FIG 1/4, FIG 1/5	12.2% -- 2 labels/96ms	Ensembles should insert two label FIGs in every transmission frame.
FIG 2/1, FIG 2/4, FIG 2/5	22.8% -- 2 labels/96ms	

TABLE 1: FIC share for high volume FIGs in ensembles with more than 20 services

FIG prioritisation

As DAB ensembles may use a large variety of FIC features and functions, various FIG types must be carefully prioritised within the remaining capacity. FIG types can be categorised by timing requirements. For each category, guideline rules should be respected for the best user experience, listed below in order of priority:

- **Fixed insertion:** FIG 0/0 and FIG 0/7 must always be placed in the first FIB at the beginning of a transmission frame.
- **Timing critical:** FIG 0/19 and FIG 0/26 (announcement switching) should be inserted 10/sec in bursts at the beginning and at the end of an announcement. This burst rate is critical for

receiver performance and must always be maintained. FIG 0/6 (short form) signals a change of database and should be inserted in regular intervals (activation state) or in a burst (CEI). FIG 0/9 provides the ECC critical for service identification and should be inserted once per second.

- **Fixed share:** core MCI and labels combined represent the bulk of FIC data and should be inserted at a fixed rate. The ensemble label (FIG 1/0, FIG 2/0) should be inserted to match the repetition cycle time of service labels.
- **Scaled insertion:** FIG 0/3, FIG 0/5, FIG 0/8, FIG 0/13, FIG 0/14, FIG 0/17, FIG 0/18, FIG 0/25 should be inserted at a rate to maintain a repetition rate not exceeding the repetition rate of labels for the ensemble (i.e. the time taken to deliver all the labels for the ensemble should also be the time taken to deliver all of these FIGs).
- **Best effort:** Service following and service linking information (FIG 0/6, FIG 0/21, FIG 0/24) often represents a large database of linkage information and should utilise remaining capacity to convey all data within 2 minutes.

Reconfigurations

During a 6 second reconfiguration period, two sets of ensemble configuration information (MCI current, next) must be signalled. This is achieved by doubling the repetition cycle time of the combined information. Furthermore, ensembles must ensure that all information (MCI, SI) for the 'current' configuration is signalled during the reconfiguration period at least once.

Announcements

At the start and end of announcements, the respective announcement switching information (FIG 0/19, FIG 0/26) shall be signalled in a burst of 10/second. Ensembles should ensure this burst rate is achieved for the burst duration and may extend the cycle time for **scaled insertion** FIGs temporarily.

Structured FIGs

A number of MCI and SI FIGs are structured per sub-channel, service or service component. Care must be taken that all sub-fields are **evenly repeated**, so that every sub-channel, service and service component has the same repetition time on average. If a fixed insertion sequence of sub-fields cannot be guaranteed, it is critical to keep the variation of the cycle time of any sub-field as low as possible.

Worst case cycle times

As the insertion of the large number of different FIG types each with different timing requirements represents a complex balance, care must be taken to not exceed worst case cycle times.

According to the guidance discussed above, the cycle time of service labels can be considered the maximum cycle time for SI information. Ensembles should seek to not exceed the cycle time of labels for **scaled insertion** FIGs. Ensembles should not exceed a cycle time of 2 minutes for service linking information (FIG 0/6).

While cycle times must be guaranteed on average, care must also be taken to limit the maximum distance between FIGs and FIG sub-fields. To limit worst case latency, variation of the cycle time for FIGs and FIG sub-fields shall be kept at a minimum.

Ensemble acquisition procedure

When tuning into an ensemble, a receiver starts to collect all FIC information to build up internal databases, including the user visible service list. While ensembles with a large service count cannot maintain nominal repetition rates for FIC data, receivers should make efforts to build a complete service list in every case.

Two mechanisms can be utilised to establish the number of services in an ensemble. If FIG 0/7 is available, the number of services is directly signalled. If FIG 0/7 is not available, the number of services can be determined from FIG 0/2 after all information has been received. As the cycle time of FIG 0/2 may scale with number of services, receivers should ensure a sufficient wait time for FIG 0/2 completion.

Receivers should apply sufficient wait time also for all service labels to be received, after the number of services has been determined. Receivers may terminate the wait after a time-out to avoid excessive ensemble acquisition times in cases ensembles do not signal all service labels, or when the label cycle time exceeds worst case boundaries.

Receivers should be able to acquire ensembles where all FIC information is carried three times slower than at its nominal repetition rate: i.e., the receiver should be able to cope with ensembles where labels are carried only every 3 seconds and where core MCI is repeated every 288 ms (or every 576 ms during reconfigurations).

ANNEX (informative)

Charts

Core MCI cycle time over number of services and core MCI share.

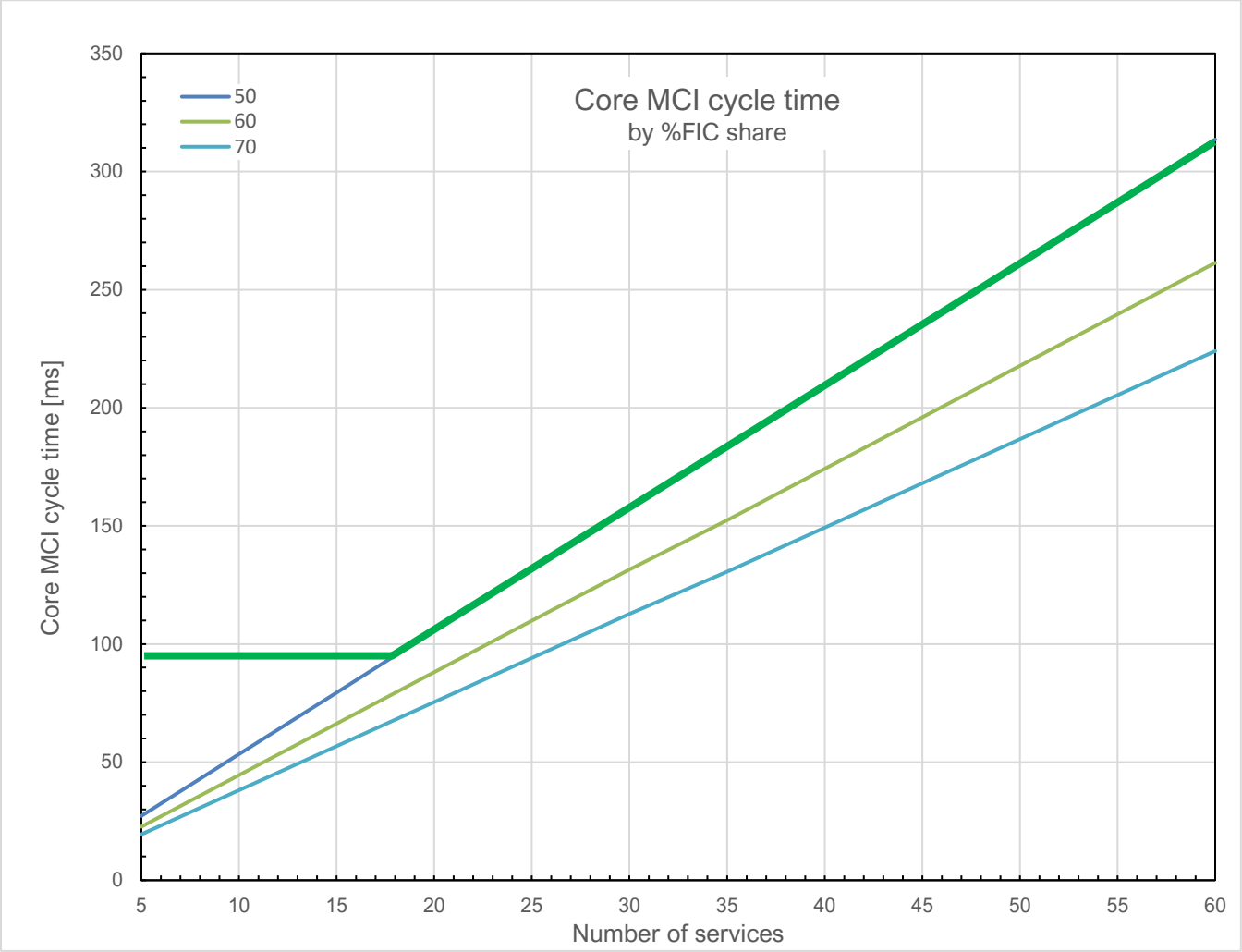

FIGURE 1: Cycle time of core MCI over number of services per ensemble, each coloured line represents a share of gross FIC capacity (in %) for core MCI. The thick green line gives the guideline cycle time for core MCI.

EXAMPLE: the dark blue line represents a share of core MCI of 50%. This is an average data capacity for core MCI of 180 bytes per transmission frame (96 ms). In an ensemble with 35 services (totalling 343 bytes of core MCI information), the cycle time of core MCI is 183ms (assuming a 90% load factor).

Service label cycle time over number of services and labels share

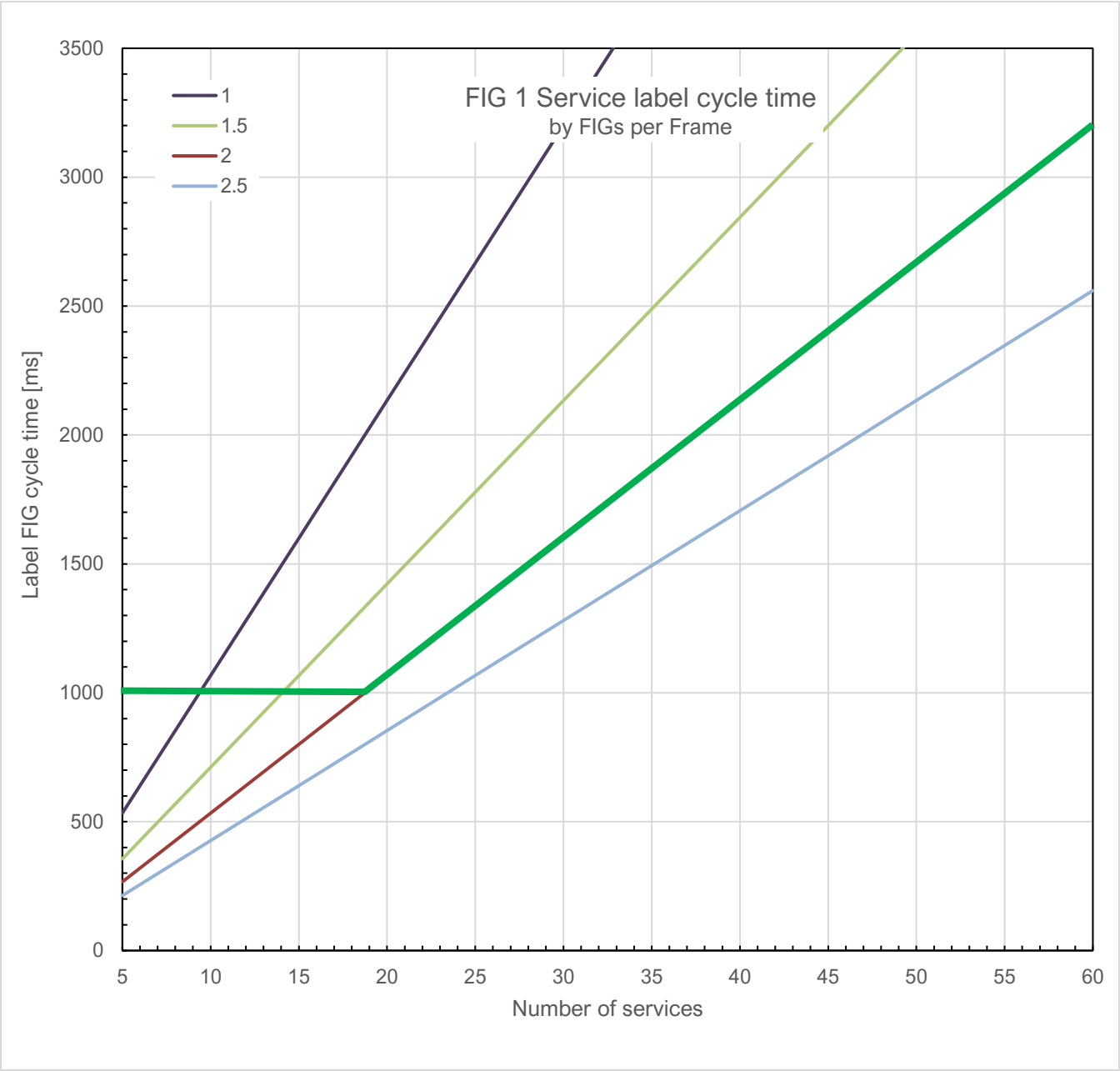

FIGURE 2: Cycle time of FIG 1 service label information by number of services. Each line represents a fixed (average) number of FIG 1 labels per frame. For example, the orange line shows the cycle time of all FIG 1 information if two FIG 1 labels are inserted in every transmission frame (96 ms). The thick green line indicates the guideline cycle time for FIG 1 labels.

Service label cycle time over number of services and labels share

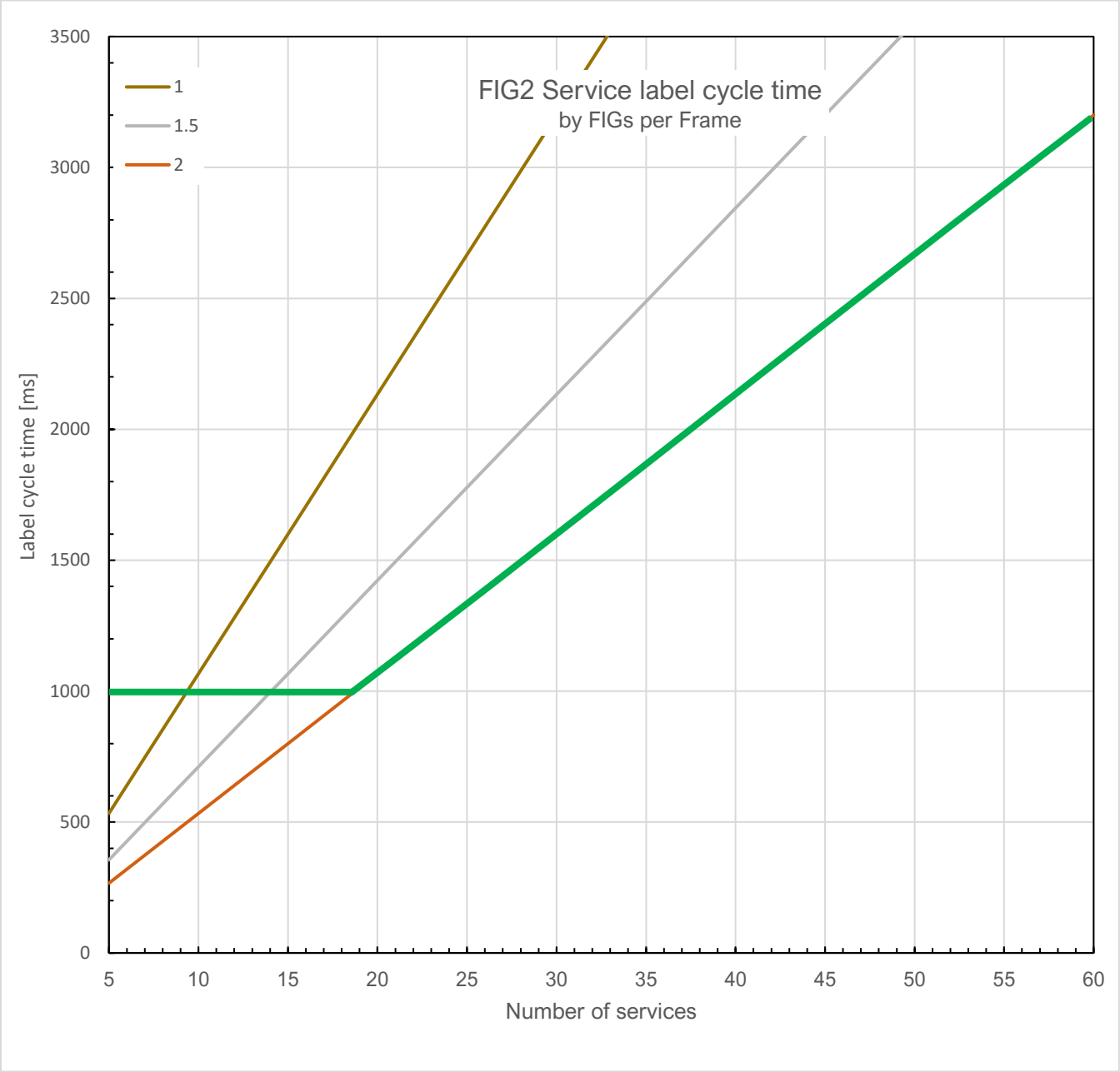

FIGURE 3: Cycle time of FIG 2 service label information by number of services. Each line represents a fixed (average) number of FIG 2 labels per transmission frame. For example, the orange line shows the cycle time of all FIG 2 information if two complete FIG 2 labels are inserted in every transmission frame (96 ms). The thick green line indicates the guideline cycle time for FIG 2 labels.

Ensemble encoding examples

The guidance in this document has been devised from an in-depth analysis of existing ensembles and model computations. In fact, reports of issues with on-air ensembles were the prime motivation for this work. Understanding why receivers had been observed not picking up an ensemble in part or in full were unclear until a review of repetition cycles.

To put findings and recommendations into context some of the data reviewed is presented here. Table 2 gives the FIC load factor for four example ensembles with high service count – two test ETI files (TEST_1, TEST_2) and two on-air ensembles (REAL_1, REAL_2).

	TEST_1	TEST_2	REAL_1	REAL_2
Number of services	36	40	31	32
FIC load factor (%)	79.98	83.54	89.71	88.88

TABLE 2: Number of services and FIC load factor in four example ETI files.

All these ensembles carry more than 30 services: the two test files serve as benchmark examples with 36 and 40 services. TEST_1 and TEST_2 represent fully configured ensembles with extensive SI, TEST_1 also carries extensive linking data.

	TEST_1	TEST_2	REAL_1	REAL_2
Fixed insertion	1.9	2.7	1.7	1.7
Core MCI	67.5	69.8	90.4	77.5
Labels	13.2	15.6	6.5	11.5
Scaled insertion	17.2	12.0	1.5	9.3
Best effort	0.1	0.0	0.0	0.0

TABLE 3: Share of used FIC capacity (%) between FIG categories.

When looking at the share of the FIC data using the categories introduced above, it can be seen that both real-world files over-prioritise core MCI at the expense of capacity for SI and labels, especially in the case of REAL_1.

	TEST_1	TEST_2	REAL_1	REAL_2
Min	2.01	1.76	2.14	1.82
Max	2.02	1.78	4.00	1.92

TABLE 4: Minimum and maximum repetition cycles (seconds) of service labels.

As Table 4 shows, REAL_1 also has an uneven provision of labels, some taking twice as long to arrive as others. The ETI file examined is a snapshot of an ensemble that has been reported to cause issues with receivers.