February 2024

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Recommended Citation
Chiang, Karl; Chen, Alan; Lee, Jehyoung; McDonnell, Nicholas M.; Hsu, Andy; Lai, Lendan; Lai, Jerry; and Lin, Chisa, "Reducing Wireless Harmonics using Dynamic Spread Spectrum Clocking and Dynamic Adaptation of MIPI Frequency", Technical Disclosure Commons, (February 08, 2024)
https://www.tdcommons.org/dpubs_series/6669

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Reducing Wireless Harmonics using Dynamic Spread Spectrum Clocking and Dynamic Adaptation of MIPI Frequency

ABSTRACT

Harmonics of digital signals generated by components of a mobile device can get coupled to useful signals via the device antenna and appear as noise and desensitize the receiver. This disclosure describes techniques of dynamic spread spectrum clocking (SSC) and dynamic MIPI (mobile industry processor interface) frequency adjustment to arrest the degradation of receiver/antenna performance caused by harmonics generated by device components. Examples of device components include the camera, the MIPI serial interface of the display, the DDIC (display driver integrated circuit) oscillator, etc. Problematic frequency ranges, e.g., frequency ranges of communication channels rich in harmonics generated by components, are identified. SSC is selectively enabled or disabled to reduce or eliminate interference. The MIPI frequency is adjusted such that MIPI harmonics do not fall in presently used communication channels.

KEYWORDS

- Antenna coupling noise
- Receiver sensitivity
- Spread spectrum clocking
- Dynamic SSC
- MIPI serial interface
- Display driver integrated circuit (DDIC)
- Harmonics reduction
- Receiver desensitization
- Electromagnetic interference

BACKGROUND

Harmonics of digital signals generated by components of a mobile device such as a smartphone, tablet, wearable device, etc. can get coupled to useful signals via the device antenna and appear as noise and desensitize the receiver.

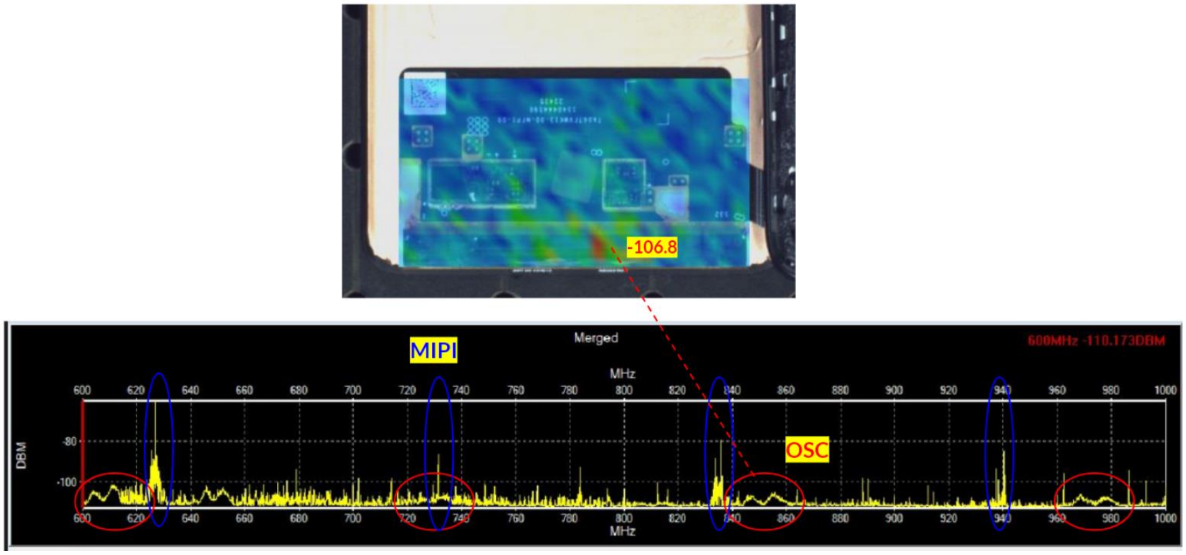


Fig. 1: Power spectral density when static SSC is used to mitigate electromagnetic interference

Spread spectrum clocking (SSC) is a technique to reduce noise and receiver desensitization by distributing the clock energy over a broad frequency range. In particular, the energy of the fundamental clock frequency is distributed to minimize energy peaks at specific frequencies. Where SSC has been implemented, it is static, e.g., it is always on or always off.

While this results in some reduction in electromagnetic interference (EMI), the reduction is uneven. For example, illustrated in Fig. 1 is a power spectral density (PSD) of electromagnetic emissions from a device with static SSC. While the harmonics (red ovals marked ‘OSC’) from the display driver integrated circuit (DDIC) oscillator are relatively low and broad, the spurs from the mobile industry processor interface (MIPI) serial interface (blue ovals marked ‘MIPI’) are substantial and spiky. The resulting broadband noise can severely desensitize the receiver.

DESCRIPTION

This disclosure describes techniques of dynamic spread spectrum clocking (SSC) and dynamic MIPI frequency adjustment to arrest the degradation of receiver/antenna performance caused by harmonics generated by device components. Examples of device components include the camera, the MIPI (mobile industry processor interface) serial interface of the display, the DDIC (display driver integrated circuit) oscillator, etc. Problematic frequency ranges, e.g., frequency ranges of communication channels rich in harmonics generated by components, are identified. SSC is selectively enabled or disabled to reduce or eliminate interference. The MIPI frequency is adjusted such that MIPI harmonics do not fall in presently used communication channels.

The current operating frequency, e.g., communication channel, of the receiver is obtained by querying the relevant frequency tables of the communication mode (e.g., WiFi, LTE, etc.). If the receiver sensitivity of the current communication channel is found to be affected by the harmonics of a component of the device, e.g., camera, display MIPI/oscillator frequency, etc., the frequency of the component is changed and/or spread spectrum clocking is enabled for the duration of use of the communication channel.

Harmonic reduction can be conveniently fine-tuned via software settings. For example, changing the frequency of a component or enabling/disabling SSC can be done via a software API (application programming interface) of the component. Furthermore, if the changed frequency of the component is found to continue causing interference on the communication channel, then it can be changed again one or more times until interference is reduced.

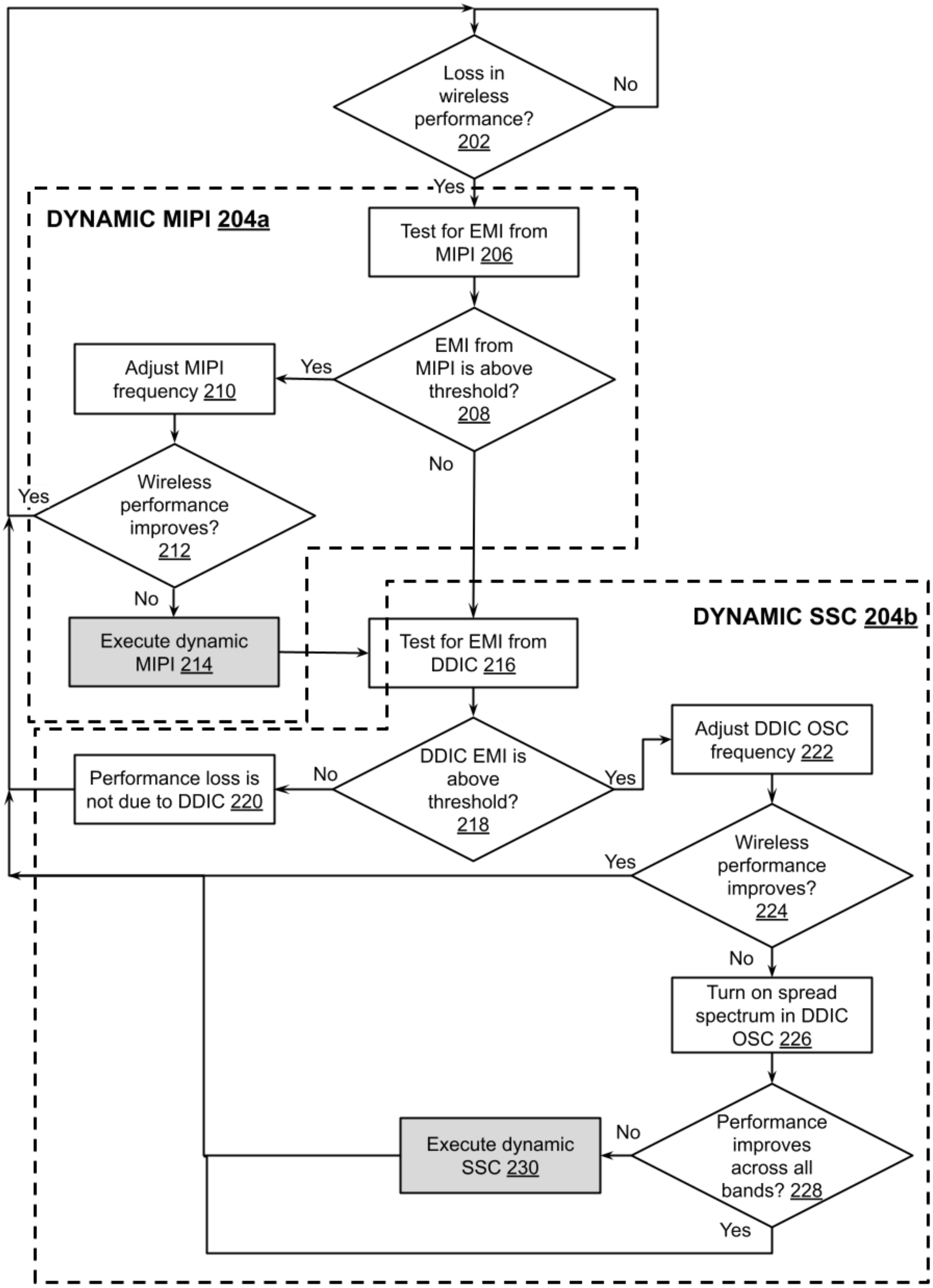


Fig. 2: Reducing wireless harmonics using dynamic spread-spectrum clocking and dynamic adapting of the MIPI frequency

Fig. 2 illustrates reducing wireless harmonics using dynamic spread-spectrum clocking and dynamic adapting of the MIPI frequency. The procedure illustrated in Fig. 2 can be used to determine the cause of receiver desensitization and remedy it. Receiver desensitization can occur due to electromagnetic interference (EMI) or harmonics generated by various components onboard the device (known as aggressors) during the course of their operations, e.g., the display (during white, flicker, or video playback), the front or rear cameras (during preview, video capture), etc.

When a loss in wireless performance is detected (202), one or both of the following procedures are executed: dynamic MIPI (204a) or dynamic SSC (204b). The procedures can be executed serially or in parallel. If executed serially, they can be executed in any order. In the illustrative example of Fig. 2, dynamic MIPI is followed by dynamic SSC.

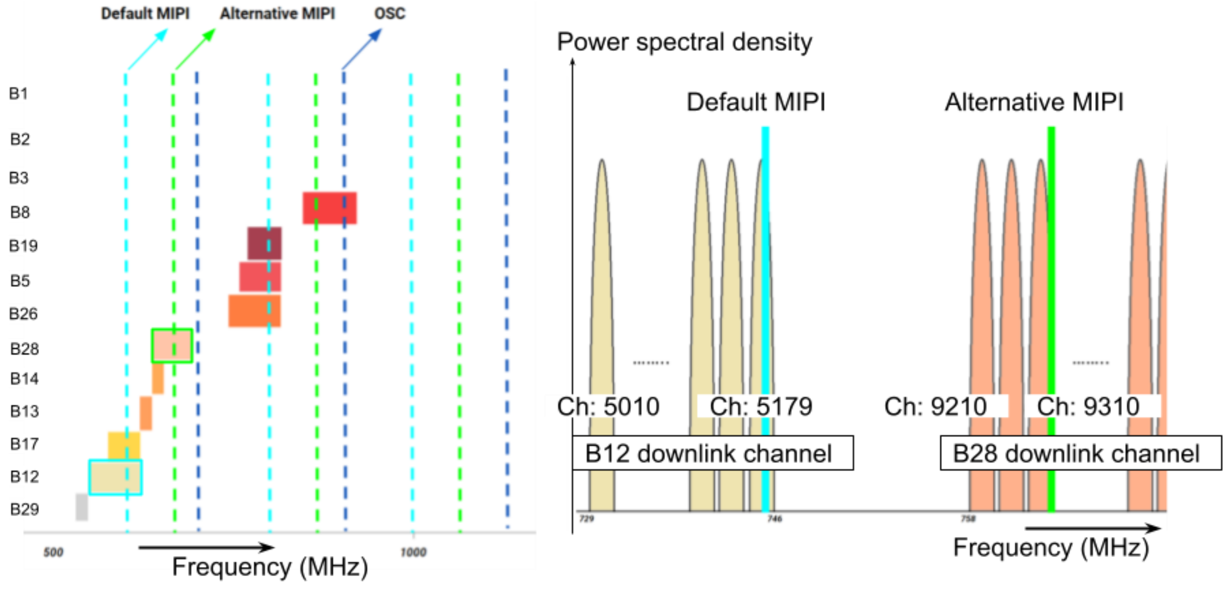
Dynamic MIPI (204a) is carried out by testing (206) for EMI from the MIPI serial interface. If the EMI from the MIPI serial interface is above a threshold value (208), the MIPI frequency is adjusted (210). If the wireless performance does not improve (212), dynamic MIPI frequency adjustment, explained in greater detail below, is executed (214). If necessary after frequency adjustment, dynamic SSC (204b) is carried out.

Dynamic SSC (204b) is carried out by testing for EMI from the DDIC oscillator (216). If the DDIC EMI is below threshold (218), performance loss is determined (220) to not be from the DDIC. If the DDIC EMI is above threshold (218), the DDIC oscillator frequency is adjusted (222). If the wireless performance does not improve (224), spread spectrum clocking is turned on in the DDIC oscillator (226). If the wireless performance does not improve in all bands (228), e.g., if the performance improves in some bands while deteriorates in others, then dynamic spread spectrum clocking, explained in greater detail below, is executed (230).

Dynamic MIPI frequency adjustment (214): When a band used by the device for communication is determined to be affected by harmonics of the MIPI frequency, the MIPI frequency is changed to avoid its harmonics from falling on the communication band, thereby remediating antenna/receiver desensitization. When the device leaves the communication band, the MIPI frequency automatically reverts to its prior setting.

Example: The device is communicating over the 4G/LTE B11 (1500 MHz) band. The MIPI frequency is currently at 500 MHz, and a MIPI harmonic is interfering with device communications. Under dynamic MIPI frequency adjustment, the MIPI frequency is changed from 500MHz to 551MHz, and the interference is resolved. When the device leaves the 4G/LTE B11 (1500 MHz) band, the MIPI frequency automatically reverts to 500MHz.

Dynamic spread spectrum clocking (230): When the band used by the device for communication is determined to be affected by harmonics of the display OSC clock, the spread spectrum clock mechanism of the display oscillator is enabled. When the device leaves the communication band, dynamic SSC is disabled.



(a) (b)

Fig. 3: (a) 4G/LTE center frequencies and bands, and EMI frequencies from the MIPI and the DDIC oscillator; (b) Moving the default MIPI frequency so that it does not overlap with a communication band currently being used.

Fig. 3 illustrates dynamic MIPI frequency adjustment to ensure that EMI from the MIPI does not overlap with a communication band currently being used. Fig. 3(a) illustrates 4G/LTE center frequencies and bands. Harmonics from the default MIPI frequency are shown in light blue dotted lines. The harmonics from the DDIC oscillator are shown in dark blue dotted lines. The communications band under use is B12.

Overlap of a harmonic of the default MIPI operating frequency with the communication band B12 is detected. The MIPI frequency is changed such that the harmonic (green dotted line) falls on band B28, which is currently unused. Fig. 3(b) is a magnified view of dynamic MIPI frequency adjustment, which, again, shows the movement of the MIPI frequency such that its harmonics avoid a communication band under use (B12, light blue line) and are made to reside in a communication band not currently in use (B28, light green line). From the user perspective, a drop in downlink throughput (due to the interfering harmonic at B12) is reversed such that the user experiences an increased data throughput.

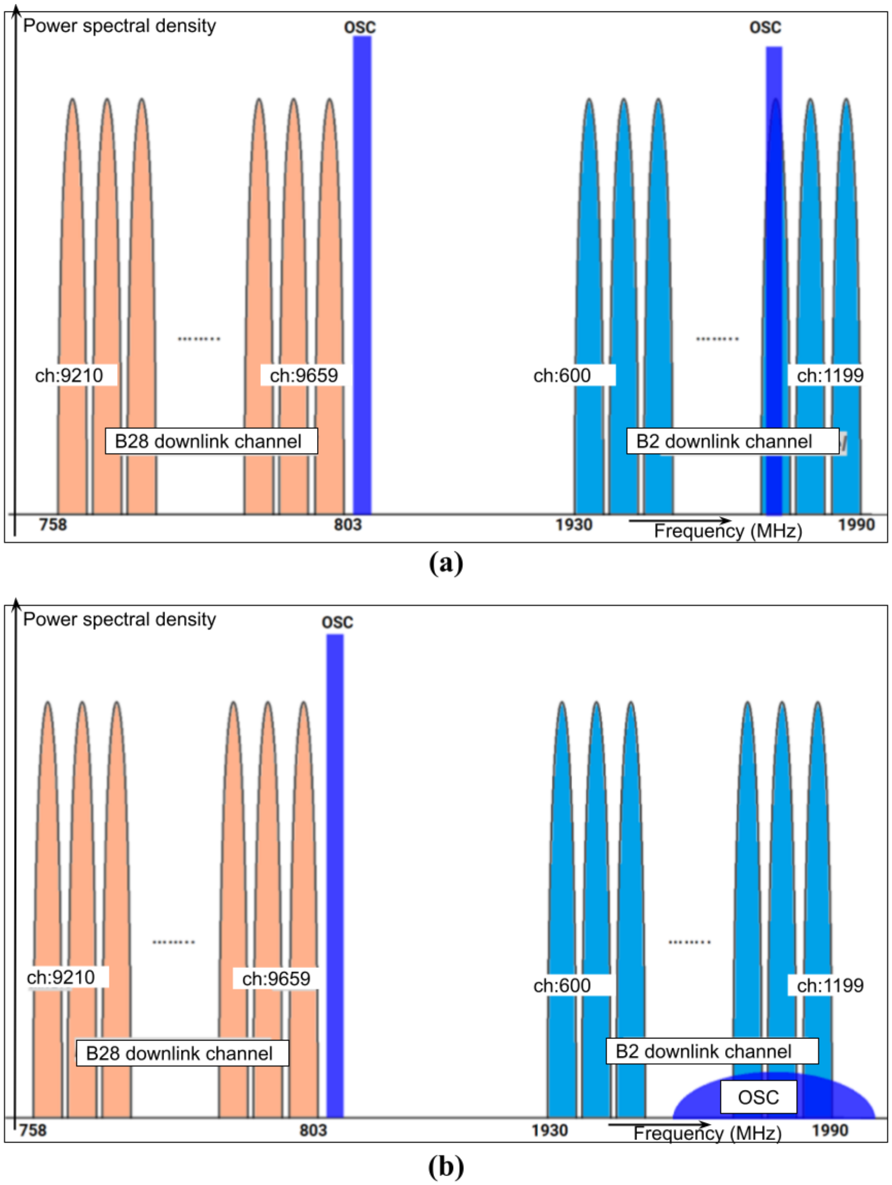
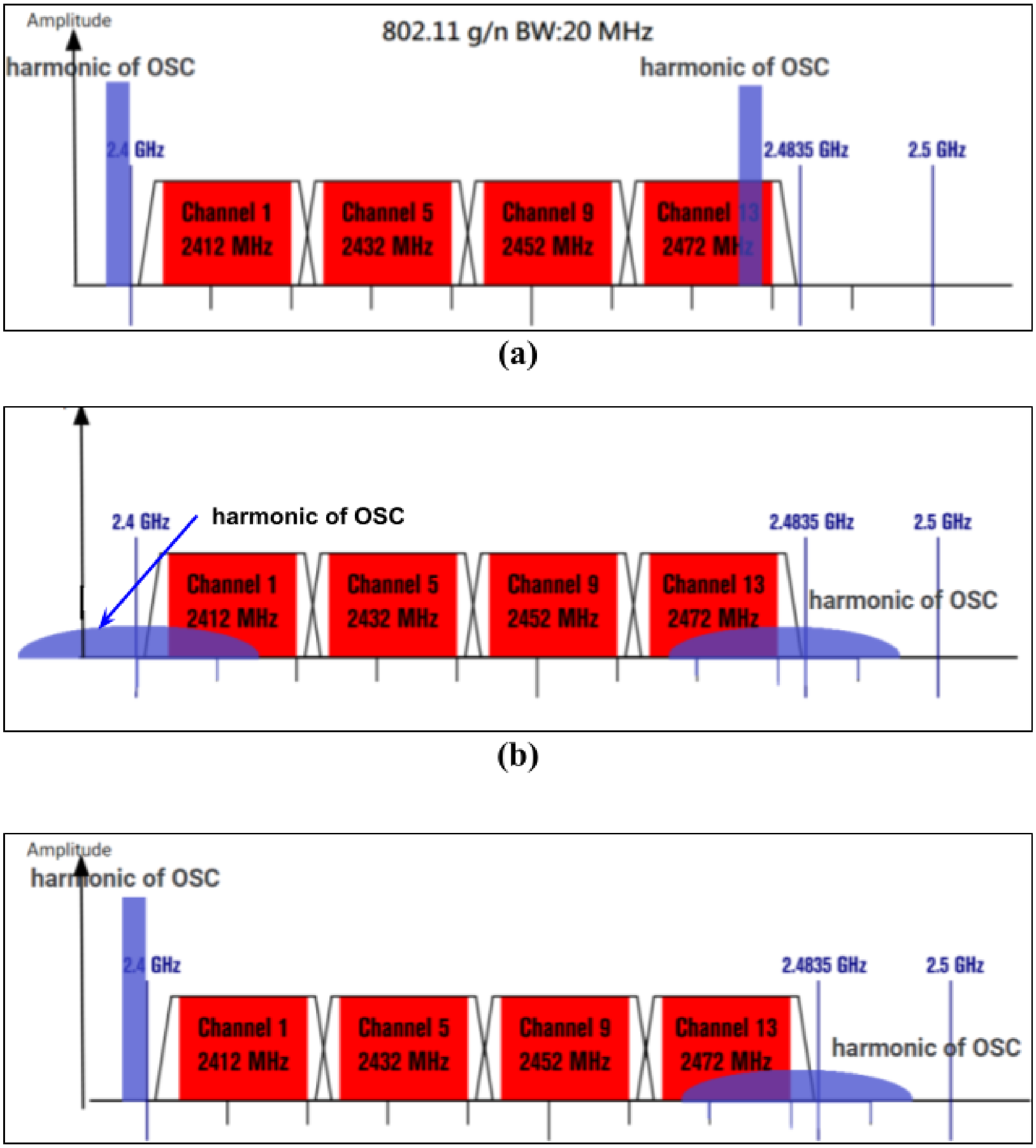


Fig. 4: (a) A harmonic of the DDIC oscillator interfering with a 4G/LTE communications channel (B2) under use; (b) The energy of the interfering harmonic is spread across frequency such that its effect on receiver desensitization and the quality of communication is ameliorated.

Fig. 4(a) illustrates harmonics (dark blue lines) of the DDIC oscillator, one of which narrowly misses interfering with an 4G/LTE channel under use (B28), and another which interferes with a 4G/LTE communications channel (B2) under use. Upon detecting that the DDIC oscillator is interfering with channel B2, spread spectrum clocking is turned on, which distributes the energy of the interfering harmonic across frequency, such that its power spectral density greatly reduces (Fig. 4b, dark blue oval), thereby ameliorating its effect on receiver desensitization and the quality of communications.



(c)

Fig. 5: Using spread spectrum clocking to ameliorate the effect of DDIC oscillator harmonics (a) Two harmonics (purple lines) of the DDIC oscillator; (b) Subjecting both harmonics to SSC improves Channel 13 but adds to the noise of Channel 1; (c) Selectively applying SSC to Channel 13 improves Channel 13 while retaining the quality of Channel 1.

Fig. 5, which is a spectral representation of channels 1, 5, 9, and 13 of WiFi (802.11g/n), illustrates the selective use of spread spectrum clocking to ameliorate the effect of DDIC oscillator harmonics. Fig. 5(a) illustrates that although the DDIC oscillator generates two harmonics (purple lines), only one of them overlaps with a channel (Channel 13, at 2472 MHz); the other is to the left and clear off the nearest channel under use (Channel 1, at 2412 MHz).

Under a conventional SSC scheme (Fig. 5b), both harmonics are subject to spread spectrum clocking. Consequently, the energy of both purple lines is spread across frequency and their power spectral densities reduce. While Channel 13 is clearly benefited (as its interferer now has low spectral density and has half its energy spread outside of Channel 13), the quality of Channel 1 actually worsens, because some interference energy now overlaps with and spills into Channel 1.

Per the dynamic SSC techniques described herein (Fig. 5c), the harmonic that overlaps with a channel under use (such as Channel 13) is subject to SSC, while other harmonics are not subject to SSC. Doing so, the quality of Channel 13 improves, while the quality of Channel 1 is maintained without deterioration.

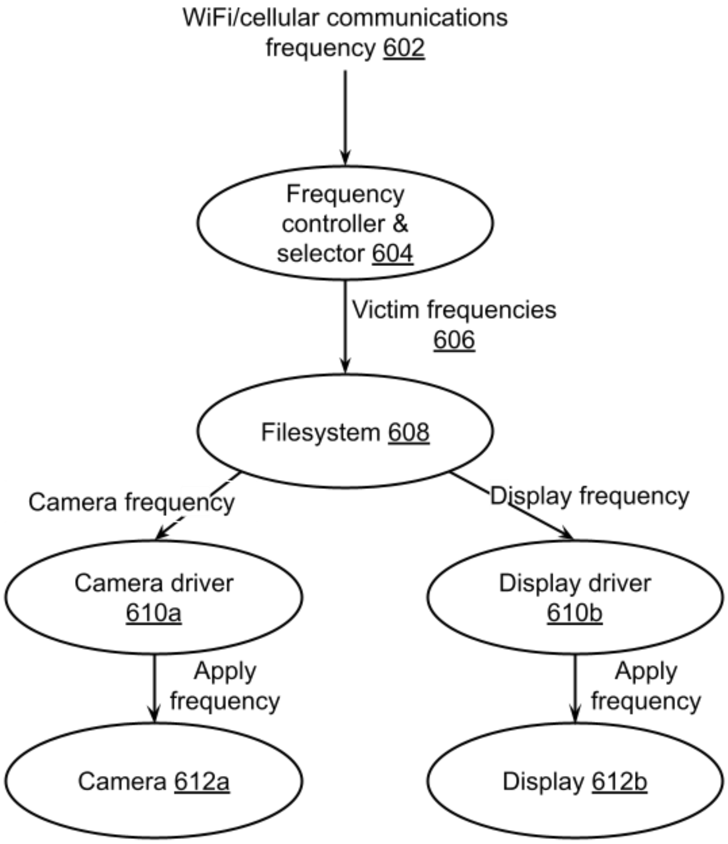


Fig. 6: Process flow

Fig. 6 illustrates an example process flow. A frequency controller and selector module (604) maintains a list of preferred operating frequencies for each component, e.g., front camera, primary display, etc. of the device. Initially, the list is empty. When the frequency controller/selector receives a WiFi or cellular frequency (602), it checks (in its cache) to see if it is the same as the frequency currently being used. If it is the same, no action is taken. If it is different, the incoming frequency is cached, and, for each component, the frequency controller/selector does the following.

- *Looks up the coexistence table*: A coexistence (coex) table includes a mapping of a preferred component operating frequencies and aggressor frequencies. Each component has a pre-made coex table associated with it and stored in the filesystem of the device.

- *Selects the operating frequency of the component*: An aggressor frequency is compared to table entries. If the aggressor frequency is close enough to the problematic range, the preferred frequency is added to the list of preferred frequencies. If the aggressor frequency is not close enough to any table entry, then all the component frequencies defined in the table are added to the list of preferred frequencies. The criterion for determining whether an aggressor frequency is close enough to a problematic range is as follows. The preferred frequency of a problematic range is added to the list if the following two conditions are met:

```
aggressorFrequency + aggressorBandwidth/2 >= problematicRangeLowerBound
aggressorFrequency – aggressorBandwidth/2 <= problematicRangeUpperBound
```

Example

A device receives WiFi at 2 GHz, specifically at the 2412 MHz channel with the default WiFi bandwidth of 20 MHz. The aggressor frequency of 2412 MHz overlaps with the two problematic ranges [2420 MHz, 2434 MHz] and [2411 MHz, 2413 MHz], determined as follows.

```
[2420 MHz, 2434 MHz]
      Lower Bound: 2412 + 20/2 = 2422 >= 2420
      Upper Bound: 2412 – 20/2 = 2402 <= 2434
[2411 MHz, 2413 MHz]
      Lower Bound: 2412 + 20/2 = 2422 >= 2411
      Upper Bound: 2412 – 20/2 = 2402 <= 2413
```

- *Sends victim frequencies to a filesystem* (606) The frequency controller/selector sends the list of preferred frequencies of each component to a filesystem (608), which saves them to a device file using standard interfaces.

Device drivers (610a-b) for various components read the file saved by the filesystem and update the frequencies used by the hardware (612a-b) based on the preferred frequency read from the file.

CONCLUSION

This disclosure describes techniques of dynamic spread spectrum clocking (SSC) and dynamic MIPI (mobile industry processor interface) frequency adjustment to arrest the degradation of receiver/antenna performance caused by harmonics generated by device components. Examples of device components include the camera, the MIPI serial interface of the display, the DDIC (display driver integrated circuit) oscillator, etc. Problematic frequency ranges, e.g., frequency ranges of communication channels rich in harmonics generated by components, are identified. SSC is selectively enabled or disabled to reduce or eliminate interference. The MIPI frequency is adjusted such that MIPI harmonics do not fall in presently used communication channels.