UNITED STATES PATENT APPLICATION

For

ORTHOGONAL OFDM SUBCARRIERS BETWEEN DOCSIS AND LTE/5G NETWORKS

INVENTORS:

RUOYU SUN
HSINCHIH LIN

Description

DOCSIS and mobile networks share a large portion or spectrum that generate interference for each other if there is a leakage point in a cable plant. DOCSIS 3.1 uses 25 or 50 kHz subcarrier spacing while LTE uses 15 kHz subcarrier spacing. If DOCSIS subcarrier spacing could be adjusted to 15 or 30 kHz, along with synchronization between DOCSIS and mobile networks, the mutual interference could be reduced by orthogonality of OFDM.

Background

LTE ingress into DOCSIS:
DOCSIS and mobile networks share a large portion or spectrum that generate interference for each other, including 400, 600, 700, 800 and 900 MHz bands. CableLabs has done many works investigating LTE ingress into DOCSIS networks (https://community.cablelabs.com/wiki/plugins/servlet/cablelabs/alfresco/download?id=91b2c4f2-d936-4b20-ba13-bc5ddc4cf43d).
Cable operators are suffering such an LTE ingress in their cable plant, see attached analysis. A set of field data shows 25% of cable modems are impacted by AT&T (LTE band 12 downlink: 729-746 MHz) and Verizon (LTE band 13 downlink: 746-756 MHz). The intensity of the LTE ingress is 14.75 dB. Up to 40% of subcarriers are impacted.

OFDM design in DOCSIS, LTE and 5G NR:
DOCSIS 3.1 uses OFDM with subcarrier spacing of 25 or 50 kHz, which was limited by the 4k or 8k FFT size due to DSP capability many years ago. Nowadays, DSP chip sets can easily process a much larger FFT size that enables various subcarrier spacing in DOCSIS network. LTE uses 15 kHz subcarrier spacing. 5G defines multiple options of subcarrier spacing including 15, 30 and 60 kHz for lower bands and 60, 120 and 240 kHz for higher frequency bands. OFDM provides orthogonality between subcarriers. However, there is no orthogonality between DOCSIS and mobile networks.

Method:
The impact of mutual interference (ingress/egress) could be mitigated by utilizing OFDM orthogonality if DOCSIS and mobile networks use identical subcarrier spacing and sync the start frequency. The impact could be evaluated in lab by following steps:
1. DOCSIS subcarrier spacing could be adjusted to 15 kHz on a signal generator or prototyping device
2. Sync the start and stop frequency between DOCSIS and mobile network. (In field, a cable modem could sync with mobile network by listening broadcast channel.)
3. Compare MER or BER with orthogonal subcarriers (15 kHz) or non-orthogonal subcarriers (25 or 50 kHz).

Application:
The cable industry is considering extending frequency to and beyond 1.8 GHz or 3 GHz. More bands will overlap with mobile network. New waveforms and DOCSIS physical layer design

are being studied. This invention disclosure investigates a new OFDM subcarrier spacing selection for DOCSIS network to mitigate mobile network ingress.

LTE ingress observed in a cable operator's field DOCSIS 3.1 network

A cable operator provided field MER data for 24,767 DOCSIS 3.1 cable modems (CMs). The active DOCSIS 3.1 downstream is allocated in two portions of spectrum: 667-774 MHz with 97 MHz bandwidth; and 793-863 MHz with 70 MHz bandwidth, as the blue bar shown in Figure 1. LTE bands 12, 17 and 13 (green and purple bars) are deployed by mobile operators in the same area. The shaded red bars show the overlapping between DOCSIS and LTE networks.

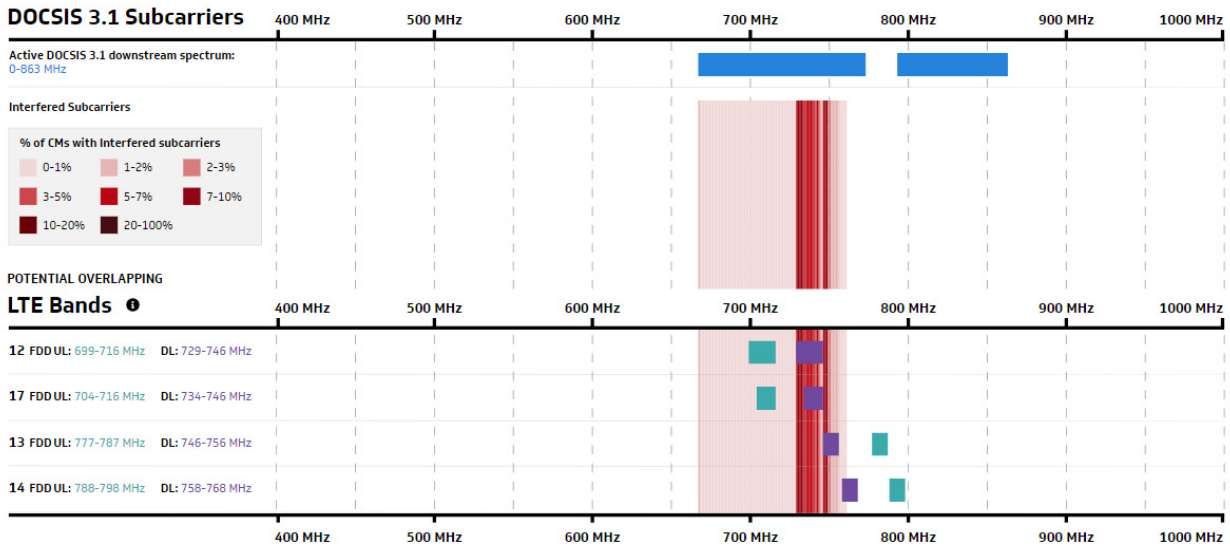


Figure 1. Spectrum of DOCSIS 3.1 and mobile networks.

Statistical analysis shows 6,309 out of 24,767 (25%) CMs are impacted. The maximum MER degradation due to LTE ingress is 14.75 dB. MER on 91 CMs reduced over 10 dB. Up to 40% of subcarriers are interfered. 322 CMs have over 25% of subcarriers impacted.

Figure 2 illustrates MER over frequency for an example individual CM. The CM occupies 70 MHz downstream bandwidth from 679 to 749 MHz. It has 1400 subcarriers with spacing of 50 kHz. This CM is interfered by LTE signals from Continuum 700, AT&T and Verizon in the market. 353 subcarriers (25%) are interfered. The ingress intensity (decrease in MER) is on average 5.5 dB with a maximum of over 10 dB.

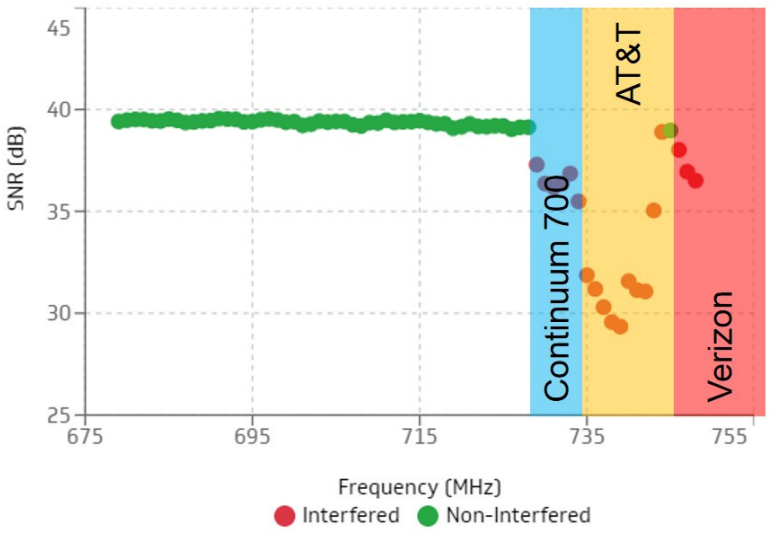
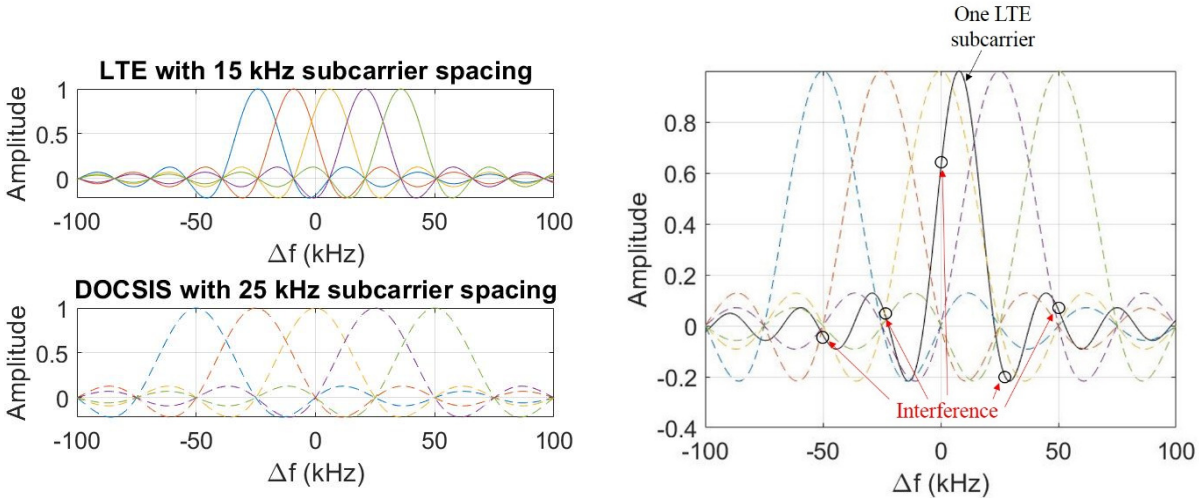


Figure 2. MER (same as SNR) over frequency for an individual CM.

Effect of orthogonality between LTE and DOCSIS subcarriers

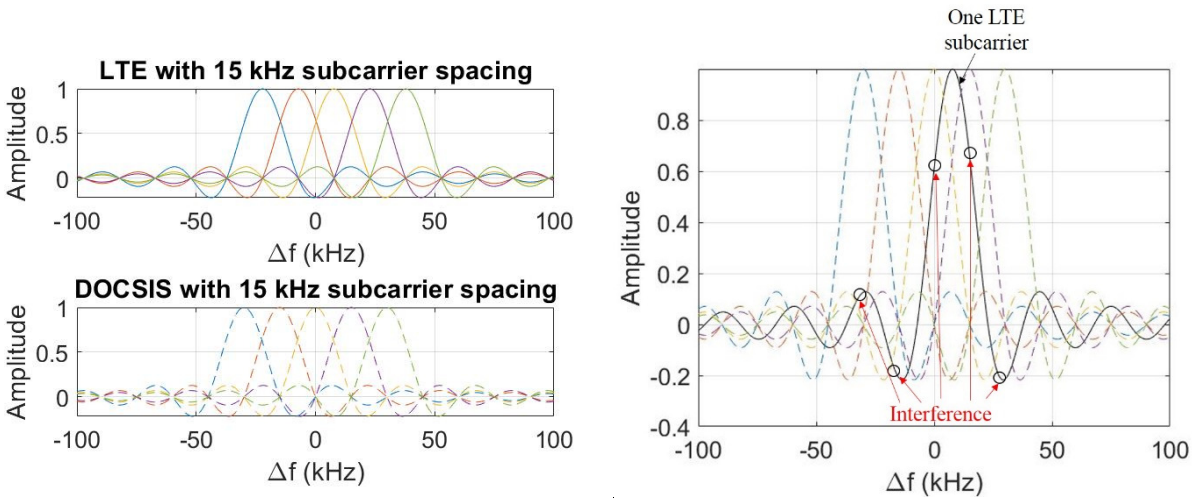
As shown in Figure 1, LTE uses 15-kHz subcarrier spacing and DOCSIS uses 25- or 50-kHz subcarrier spacing. Each LTE subcarrier generate non-zero interferences for all DOCSIS subcarriers, see Figure 1 (b).



(a) (b)

Figure 1. 25-kHz DOCSIS subcarrier spacing with random start frequency.

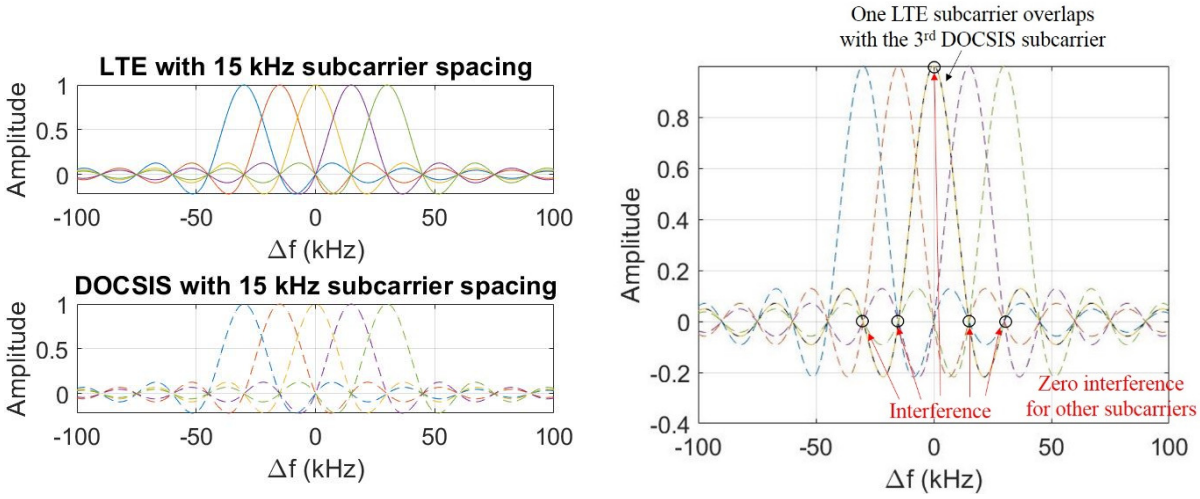
The DOCSIS subcarrier spacing is adjusted to 15 kHz, but the start frequencies between LTE and DOCSIS are not aligned, see Figure 2 (a). Each LTE subcarrier generates non-zero interference for all DOCSIS subcarriers, see Figure 2 (b).



(a) (b)

Figure 2. 15-kHz DOCSIS subcarrier spacing with random start frequency.

The DOCSIS subcarrier spacing is adjusted to 15 kHz, and the start frequencies between LTE and DOCSIS are aligned, see Figure 3 (a). Each LTE subcarrier only impact one DOCSIS subcarrier. Its interference on other DOCSIS subcarriers reduces to zero due to orthogonality of OFDM, see Figure 3 (b). This may reduce the overall LTE ingress intensity into DOCSIS network.



(a) (b)

Figure 3. 15-kHz DOCSIS subcarrier spacing with frequency synchronization.