RF Intermodulation Interference Study
202 SE Third Street Monopole

AT&T Wireless Modifications

September 2021

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INTERMODULATION (IM) STUDY
202 SE Third Street Monopole

Black and Veatch on behalf of AT&T Wireless (AT&T) is adding two C-Band block frequencies to the AT&T monopole located at 202 SE Third Street, Lee's Summit, MO. The two C-Band blocks are 3760 - 3800 MHz and 3860 - 3940 MHz. AT&T will be able to transmit and receive within each block of frequencies. Table 1 lists the existing frequencies that are installed at the site.

Licensee	Band	Tx/Rx (MHz)
City of Lee's Summit	KAJ606	Tx: 159.09, 155.37, 155.475; Rx: 155.91, 156.03, 159.09
	KCZ477	Tx: 154.22, 154.28, 154.43, 453.3875, 453.7125, 453.90; Rx: 153.8, 154.22, 154.28, 154.43, 458.3875, 458.7125, 458.90
	WQPK766	Tx: 460.3875, 460.4625; Rx: 465.3875, 465.4625
	WZN205	Tx: 155.94, 156.195, 158.745, 159.045, 453.525; Rx: 153.86, 155.94, 156.195, 158.745, 158.88, 159.045, 458.525
	Microwave: WQOT616, WQOT618, WQOT620, WQOT621, WRAU272, WRAU275, WRBR818, WRBZ462, WRBZ464	Tx:11055, 11305, 11015, 11115, 10995, 11155; Rx: 10815, 11505, 11545, 11605, 11485, 11645
AT&T	850 B	Tx: 885-890; Rx: 840-845
	LTE - 700	Tx: 734-746; Rx: 704-716
	LTE - 700	Tx: 717-722; Rx: None
	PCS	Tx: 1970-1990; Rx: 1890-1910
	WCS	Tx: 2350-2360; Rx: 2305-2315
	FirstNet	Tx: 758-768; Rx: 788-798
	AWS	Tx: 2110-2120; Rx: 1710-1720; Tx: 2170-2180; Rx: 1770-1780
	850 B	Tx: 880-885; Rx: 835-840
T-Mobile	LTE - 700	Tx: 731; Rx: 701
	LTE - 1900	Tx: 1931 - 1943; Rx: 1851 - 1863
	LTE - 2100	Tx/Rx: 2628, 2648
	800	Tx: 862.9, 866.5; Rx: 817.9, 821.5
	Microwave	Tx: 10735, 10855, 17965, 18065; Rx: 11225, 11345, 19525, 19625
Verizon	LTE - 700	Tx: 751.5; Rx: 781.5
	LTE - 2100	Tx: 2150, 2137.5; Rx: 1750, 1737.5
	LTE - 800	Tx: 871 - 892; Rx: 826 - 847

Table 1

The 700 MHz / 800 MHz / 1900 MHz / 2100 MHz / C-Band blocks use wide spectrum. Utilizing these entire spectra in the study would present tens of thousands of pages of mathematical results of the calculations for IM products. Therefore, 1 MHz samples from each of these TX and RX block were used in the intermodulation calculations. Using this sampling procedure, trends of potential interference can be determined.

Any potential IM product hits between existing frequencies at the site were ignored as there are no interference issues currently existing at the site.

Although AT&T is not collocated on a communications site with the City of Lee's Summit, MO, the City does have a communications monopole located at 207 SE Douglas St, Lee's Summit, MO (ASR#1207865) which is located 0.14 miles away from the 202 SE Third St monopole. Therefore, the City of Lee's Summit, MO has requested AT&T to perform this IM study to analyze any possible interference effects from intermodulation combinations due to the proposed AT&T frequency additions.

IM CALCULATIONS

An intermodulation study is a mathematical exercise to identify the relationships between all frequencies (transmit and receive) located at a site. The mathematical calculations are intended to indicate whether the relationship is such that two or more transmit (TX) frequencies could mix through a non-linear element at the site to produce an interfering signal on a receive (RX) frequency at the site. The mathematical relationship does not indicate that an actual interfering signal will be created or that interference will occur at the site. For this Analysis, 2-signal/3rd-order, 2-signal/5th-order, & 3-signal/3rd-order IM products as well as 2nd harmonics were calculated.

For the purpose of this Analysis, it was assumed that all existing frequencies located at the site are operating in such a manner that no current IM products are occurring. For this

report, mathematical IM interference that could occur to the existing and proposed receiver channels as a result of the introduction of the new frequencies was studied.

IM Products: For purposes of discussion, this document will refer to TX frequencies that are involved in an IM calculation as “fundamental” frequencies. The resultant IM product frequency falling within the bandwidth of an existing receive channel will be referred to as a "hit". An IM product that falls directly on an existing receive channel will be referred to as a "direct hit".

Although difficult to quantify without exact on-site measurements, components such as antennas have a natural frequency selectivity which helps prevent the reception, mixing, and generation of cross-band and out-of-band IM products. For example, an 815 MHz receive antenna may have some, although little rejection of 850-950 MHz transmit frequency power; however, if the calculated mix includes a UHF transmitter, the antenna has some natural rejection of that frequency reducing the resulting level of 806-824 MHz products. For the same reason, the probability of a UHF antenna generating the same product is reduced since it must also radiate the 806-824 MHz product. Therefore, due to the frequency selectivity of RF components, in-band (versus out-of-band and cross-band IM) products are more likely to result in actual interference.

Companion IM products are those in which the IM frequency and one of the fundamental frequencies are companion transmit and receive channel pairs. In such instances, the companion base station transmitter will always be active while the affected base station receiver is in use.

IM Sources: In order for an IM product to occur, power at the fundamental frequencies must be imposed on a non-linear element. Examples of such non-linear elements are:

- Non-linear circuits such as transmit or receive amplifiers or mixers (i.e. base station equipment)

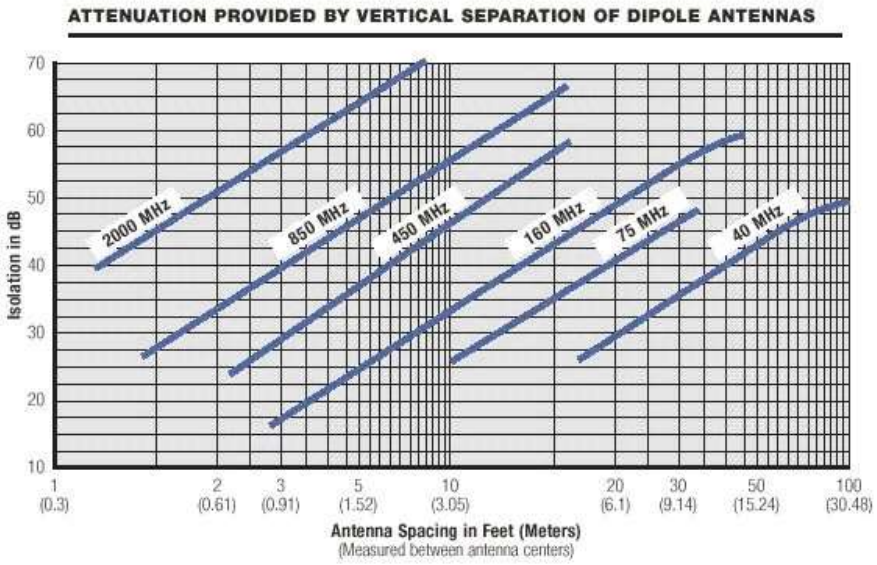
- Non-linear receive system circuits such as airport-top amplifiers or receiver multicouplers
- Junction of dissimilar metals on or near the airport or corrosion
- Intermittent connections of wires, cables, or mounting connections

In addition to the mixing at one of the above places, the product of the mix must be coupled into the receive circuitry in order for the product to actually cause measurable degradation to a receiver. Therefore, in order to prevent interference from occurring, one must eliminate the deposition of power at the point of mixing or prevent the mixed product from being coupled into the potentially affected receiver. Eliminating any one of the frequencies from the mixing point can prevent the IM product generation. The following are the general recommendations that can achieve these goals:

Transmitter-Produced Intermodulation: By providing cavity filters and isolators in transmitter output circuits, external frequencies impressed on the transmit antenna cannot enter the transmitter final amplifier where they can mix and the product can be transmitted along with the fundamentals. Once the intermodulation product frequency is generated, it cannot be filtered at the receive location since it can enter the receive network on-frequency.

Receiver Preamplifier Produced Intermodulation: By providing bandpass filters, and in some cases notch filters, transmit frequencies impressed on the receive antenna cannot enter the receiver preamplifier, receiver "front-end" amplifier, or mixer circuit where they can mix and the resultant product can interfere with the intended receive signals.

Isolation Provided by Antenna Separation



Antenna-to-Antenna Isolation: By separating any two antennas the coupling between them is reduced, which in turn reduces the level of signal received from one antenna to the other antenna. Since filters and isolators are not perfect devices, some level of power is transferred through these devices. In order to assure that the level is sufficiently low to minimize the probability of intermodulation production, it is wise to provide adequate antenna-to-antenna separation (see chart below). Vertical separation provides an approximate ten-fold increase in isolation (measured in decibels) compared to horizontal separation; therefore, 10 feet vertical separation is approximately equivalent to 100 feet of horizontal separation.

RESULTS OF STUDY

The potential theoretical IM products involving AT&T's proposed C-Band additions to the Lee's Summit, MO - 202 SE Third Street Monopole resulted in 16,381 IM product hits. These numerous hits can be narrowed down by the various factors outlined previously. The most likely IM products to occur and produce interference are those generated by frequencies in the same band of operation. These in-band hits have a higher probability of occurrence since a likely mixing source would not be able to reject these in-band frequencies. Taking into account these many factors, the results of the IM product hits caused by in-band combinations showed 7,562 possible IM product hits calculated due to in-band frequency combinations. A majority of these 7,562 IM products were the results of the proposed C-Band frequencies combining and interfering with themselves. AT&T and its C-Band equipment vendor will have the proper equipment installed at the site to prevent this occurrence.

The remaining breakdown of possible in-band IM products were zero 2-signal/3rd-order, 86 2-signal/5th-order, & zero 3-signal/3rd-order products. All 86 2-signal/5th-order in-band combinations involved AT&T's proposed C-Band frequencies. These mixes could create resultant signals that impact the City of Lee's Summit and T-Mobile microwave frequencies (11,654 MHz, 11,605 MHz, 11,545 MHz, 11,505 MHz, 11,345 and 11,225 MHz).

Similarly, there was one possible IM product hits that could affect AT&T's proposed C-Band receivers which involved two microwave frequencies (10,735 MHz and 18,065 MHz).

RECOMMENDATIONS

As the majority of the possible IM product hits involved AT&T's proposed C-Band frequencies combining to interfere with AT&T's other C-Band frequencies, AT&T and its C-Band equipment vendor will have the necessary filtering in place to prevent this occurrence. This filtering should then also prevent the same proposed C-Band frequencies from combining and creating possible IM product hits that could affect the Lee's Summit and T-Mobile microwave frequencies at the City monopole site located 0.14 miles away. The distance between the two monopoles will also create additional attenuation from any potential IM frequencies emanating from the AT&T monopole and thus reducing this possibility further. Therefore, these IM products should not occur at the City monopole site located at 207 SE Douglas Street.

The IM product listings are shown in Appendix A and can be useful if any unexpected interference does occur.

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APPENDIX A

Type	Tx Frequency 1 (MHz)	Tx Frequency 2 (MHz)		Rx Frequency (MHz)
2-Signal / 5th Order	3860	3795		11645
2-Signal / 5th Order	3861	3799		11645
2-Signal / 5th Order	3877	3863		11645
2-Signal / 5th Order	3878	3867		11645
2-Signal / 5th Order	3879	3871		11645
2-Signal / 5th Order	3880	3875		11645
2-Signal / 5th Order	3881	3879		11645
2-Signal / 5th Order	3882	3883		11645
2-Signal / 5th Order	3883	3887		11645
2-Signal / 5th Order	3884	3891		11645
2-Signal / 5th Order	3885	3895		11645
2-Signal / 5th Order	3886	3899		11645
2-Signal / 5th Order	3887	3903		11645
2-Signal / 5th Order	3888	3907		11645
2-Signal / 5th Order	3889	3911		11645
2-Signal / 5th Order	3890	3915		11645
2-Signal / 5th Order	3891	3919		11645
2-Signal / 5th Order	3892	3923		11645
2-Signal / 5th Order	3893	3927		11645
2-Signal / 5th Order	3894	3931		11645
2-Signal / 5th Order	3895	3935		11645
2-Signal / 5th Order	3896	3939		11645
2-Signal / 5th Order	3867	3863		11605
2-Signal / 5th Order	3868	3867		11605
2-Signal / 5th Order	3869	3871		11605
2-Signal / 5th Order	3870	3875		11605
2-Signal / 5th Order	3871	3879		11605
2-Signal / 5th Order	3872	3883		11605
2-Signal / 5th Order	3873	3887		11605
2-Signal / 5th Order	3874	3891		11605
2-Signal / 5th Order	3875	3895		11605
2-Signal / 5th Order	3876	3899		11605
2-Signal / 5th Order	3877	3903		11605
2-Signal / 5th Order	3878	3907		11605
2-Signal / 5th Order	3879	3911		11605
2-Signal / 5th Order	3880	3915		11605
2-Signal / 5th Order	3881	3919		11605
2-Signal / 5th Order	3882	3923		11605
2-Signal / 5th Order	3883	3927		11605
2-Signal / 5th Order	3884	3931		11605
2-Signal / 5th Order	3885	3935		11605
2-Signal / 5th Order	3886	3939		11605

2-Signal / 5th Order	3860	3895		11545
2-Signal / 5th Order	3861	3899		11545
2-Signal / 5th Order	3862	3903		11545
2-Signal / 5th Order	3863	3907		11545
2-Signal / 5th Order	3864	3911		11545
2-Signal / 5th Order	3865	3915		11545
2-Signal / 5th Order	3866	3919		11545
2-Signal / 5th Order	3867	3923		11545
2-Signal / 5th Order	3868	3927		11545
2-Signal / 5th Order	3869	3931		11545
2-Signal / 5th Order	3870	3935		11545
2-Signal / 5th Order	3871	3939		11545
2-Signal / 5th Order	3860	3935		11505
2-Signal / 5th Order	3861	3939		11505
2-Signal / 5th Order	3777	3763		11345
2-Signal / 5th Order	3778	3767		11345
2-Signal / 5th Order	3779	3771		11345
2-Signal / 5th Order	3780	3775		11345
2-Signal / 5th Order	3781	3779		11345
2-Signal / 5th Order	3782	3783		11345
2-Signal / 5th Order	3783	3787		11345
2-Signal / 5th Order	3784	3791		11345
2-Signal / 5th Order	3785	3795		11345
2-Signal / 5th Order	3786	3799		11345
2-Signal / 5th Order	3772	3863		11225
2-Signal / 5th Order	3773	3867		11225
2-Signal / 5th Order	3774	3871		11225
2-Signal / 5th Order	3775	3875		11225
2-Signal / 5th Order	3776	3879		11225
2-Signal / 5th Order	3777	3883		11225
2-Signal / 5th Order	3778	3887		11225
2-Signal / 5th Order	3779	3891		11225
2-Signal / 5th Order	3780	3895		11225
2-Signal / 5th Order	3781	3899		11225
2-Signal / 5th Order	3782	3903		11225
2-Signal / 5th Order	3783	3907		11225
2-Signal / 5th Order	3784	3911		11225
2-Signal / 5th Order	3785	3915		11225
2-Signal / 5th Order	3786	3919		11225
2-Signal / 5th Order	3787	3923		11225
2-Signal / 5th Order	3788	3927		11225
2-Signal / 5th Order	3789	3931		11225
2-Signal / 5th Order	3790	3935		11225
2-Signal / 5th Order	3791	3939		11225