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BROADBAND: FREQUENCY OFFSETS

By RON HRANAC

Every now and then a question comes up on the SCTE-List and at technical seminars regarding whether or not frequency offsets are required for downstream digitally modulated carriers operating on aeronautical frequencies. The short answer is no. Let's see why. (A quick side note: Offsetting downstream digitally modulated carriers—which are noise-like signals—would really be of no benefit anyway. If one were to offset by 12.5 or 25 kHz what amounts to a nearly 6 MHz wide pile of noise, the frequency that was trying to be avoided would still be affected by that wideband noise-like signal.)

The first place to start is the Federal Communications Commission's rules in Part 76. Here's what those rules say about operation in the aeronautical bands.

§76.610 Operation in the frequency bands 108-137 and 225-400 MHz—scope of application.

The provisions of §76.611 (effective July 1, 1990), §76.612, §76.613, §76.614 and §76.1803 and §76.1804 are applicable to all cable television systems transmitting carriers or other signal components carried at an average power level equal to or greater than 10-4 watts across a 25 kHz bandwidth in any 160 microsecond period, at any point in the cable distribution system in the frequency bands 108-137 and 225-400 MHz for any purpose.

§76.612 goes on to discuss specific frequency offsets required for operation in the aeronautical radiocommunication and radionavigation bands. The bottom line is that cable signals carried in those bands must be offset if their average power level is equal to or greater than 10-4 watts in a 25 kHz bandwidth.

When it comes to digitally modulated carriers operating on aeronautical frequencies, one must first determine whether the digitally modulated carrier's average power level in a 25 kHz bandwidth is equal to or greater than 10-4 watts. If it isn't, then a frequency offset isn't necessary.

In cable, we're used to dealing with signal levels in dBmV, not watts. So let's first convert the FCC's 10-4 watts (0.0001 watt) to dBmV, starting with the formula E = vPR where E is volts, P is power in watts and R is resistance—or, in the case of a cable network, its 75-ohm impedance:

E = 0.0001*75
E = 0.075
E = 0.0866 volt

Multiply 0.0866 volt by 1,000 to get millivolts (mV): 0.0866 * 1,000 = 86.6 mV. From here we use the formula dBmV = 20log(mV/1 mV) to convert 86.6 mV to dBmV:

dBmV = 20log(86.6/1)
dBmV = 20 * [log(86.6)]
dBmV = 20 * [1.94]
dBmV = 38.75

At first glance, you might be tempted to think that any digitally modulated carrier on an aeronautical frequency will have to be offset, because the odds are pretty good that the carrier's average power level will equal or exceed +38.75 dBmV somewhere in the network. Take a look at the following excerpt from the FCC's rules: "…an average power level equal to or greater than 10-4 watts across a 25 kHz bandwidth…"

The important point here is average power level across a 25 kHz bandwidth. Downstream digitally modulated carriers used for Data Over Cable Service Interface Specification (DOCSIS) cable modem service have a 3 dB channel bandwidth equal to the symbol rate. A 64-QAM (quadrature amplitude modulation) digitally modulated carrier's symbol rate is 5.056941 Msym/sec, so its channel bandwidth is ~5.06 MHz. When we measure a 64-QAM digitally modulated carrier's average power level, that power is across the entire 5.06 MHz channel bandwidth.

Even though the FCC rules state that the offset requirements apply to signals exceeding 10-4 watts "carried at any point in the cable distribution system," I'm going to assume a worst-case scenario and use the cable modem termination system (CMTS) output. According to the DOCSIS Radio Frequency Interface Specification, the CMTS (or external upconverter, if used) must support an RF output power level as high as +61 dBmV. Remember, this is across the full channel bandwidth.

More calculations

OK, so what's the CMTS's +61 dBmV average power level when expressed across a 25 kHz bandwidth? It definitely won't be +61 dBmV, but some lower value. Because digitally modulated carriers are noise-like signals, we can calculate the bandwidth correction with the formula ?dB = 10log(BW1/BW2), where ?dB is the difference, in decibels, to subtract from +61 dBmV, and BW1 and BW2 are the two bandwidths of interest. The two bandwidths must be in the same units, such as Hz.

dB = 10log(5,056,941/25,000)
dB = 10 * [log(202.28)]
dB = 10 * [2.31]
dB = 23.06

Subtract 23.06 dB from +61 dBmV to get the equivalent power in a 25 kHz bandwidth: 61 dBmV – 23.06 dB = 37.94 dBmV. This says if a CMTS's downstream output average power level is +61 dBmV across the full channel bandwidth, its power in a 25 kHz bandwidth is +37.94 dBmV. This is 0.81 dB less than the FCC's +38.75 dBmV (10-4 watts) average power level limit that would mandate a frequency offset.

In case you were wondering, a +61 dBmV 256-QAM digitally modulated carrier's average power level across a 25 kHz bandwidth is +37.69 dBmV. If you prefer to use the full 6 MHz channel bandwidth for 64- or 256-QAM, the number is +37.2 dBmV. From this little exercise, it's obvious that in most cases downstream digitally modulated carriers on aeronautical frequencies do not require frequency offsets from nominal channel assignments.

I can think of one situation in which you might want to offset a digitally modulated carrier: CMTSs that can be switched to a continuous wave (CW) mode for testing or troubleshooting purposes. In such a scenario, turning a +61 dBmV digitally modulated carrier's modulation off would result in a CW carrier whose amplitude is probably very close to +61 dBmV. A CW carrier at that amplitude in the aeronautical bands would definitely have to be offset!

If your CMTS supports CW mode—and you anticipate the possibility of someday turning off modulation for whatever reason while leaving the CMTS connected to the cable system—you should consider setting the upconverter's output frequency with an appropriate offset. Be sure to account for the CMTS's actual intermediate frequency relative to the upconverter output frequency when setting that offset, though.

Ron Hranac is technical leader, HFC Network Architectures, for Cisco Systems, and former senior technology editor for *Communications Technology*. Reach him at rhranac@aol.com.