Adjacent Channels and Offsets in COFDM Systems
The Real Deal on spectral Issues

Soon after the first ENG systems were put in service, carrier offsets became one of several new concepts developed to help fight adjacent channel interference in heavily congested areas. The intent was to enable an FM carrier to be offset by plus or minus half the distance from the channel center to the channel edge, to avoid interference in an adjacent 17 MHz channel. With a nationwide 2 GHz conversion to 12 MHz channels now underway, we are once again in the same situation with regard to avoiding interference, and once again carrier offsets are a hot subject, even though COFDM is far less susceptible to adjacent interference. MRC digital ENG systems have matured through several generations since their introduction in 1999, and we have considerable field experience and customer feedback where COFDM is involved.

Offsets in Digital Mode

Adjacent channel interference has not been a significant problem for COFDM systems operating with 8 MHz pedestals centered in a 17 or 18 MHz channel at 2 GHz. When the Sprint Nextel BAS relocation requires licensees to switch to the new 12 MHz channel plan, the probability of interference in digital modes will increase with the closer spacing. On the other hand, some feel that the deployment of an 8 MHz pedestal is inefficient in a 12 MHz channel, and have suggested that equipment vendors include the choice of an 10 MHz pedestal. A further outgrowth of this thinking is the potential for using two 6 MHz pedestals in the same channel, by offsetting the pedestal plus or minus 3.0 MHz from the channel center.

Based on years of success with analog offsets, broadcasters have naturally assumed that the same results can be achieved by the use of offsets in digital modes. While MRC understands the basis for this assumption, it is important to define the conditions under which offset operation might be possible, and to correct any false expectations.

COFDM in a Congested Environment

The primary sources of interference to a desired COFDM signal are co-channel transmissions, and energy in the passband from a signal in adjacent channel. In a perfectly linear system, the adjacent channel should not cause any degradation of the desired signal unless the spacing is such that the adjacent channel COFDM RF energy crosses into the desired channel passband at some point along the slope of the envelope.

In the real world, every element in the path may have some amount of inherent non-linearity to contend with. A great deal of attention has been focused on the effect of third order intermodulation distortion (IM3), also known as spectral re-growth. On a spectrum analyzer display, IM3 appears as broadening the shoulders of the COFDM RF envelope and raising the residual noise floor on either side of the signal. The net effect of IM3 is unwanted energy in the adjacent channel that reduces the available C/I and C/N ratios in direct proportion to the interference.

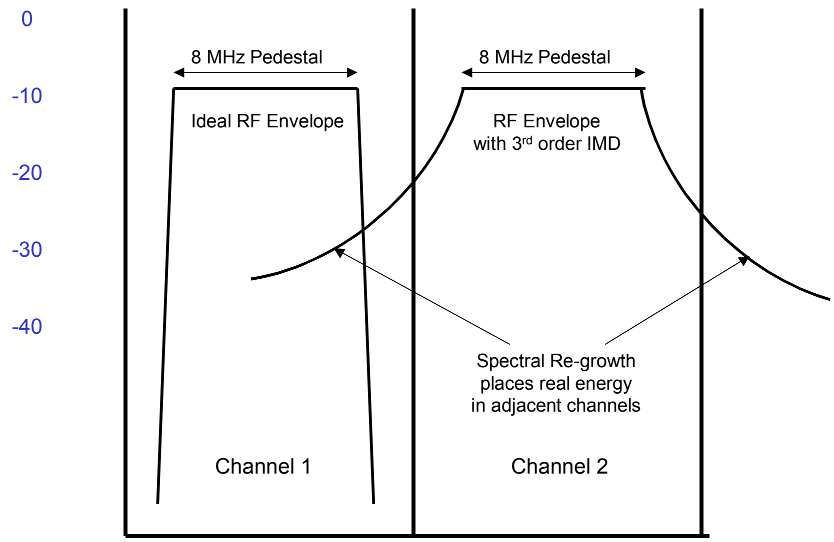

Figure 1 - Third Order Intermod due to non-linear elements

While RF and IF filters are helpful in preventing signals outside of the desired passband from entering the receiver chain, their role in preventing the effects of spectral regrowth may not be well understood. With reference to figure 1, an ideal COFDM envelope with an 8 MHz pedestal is shown in a 12 MHz channel, just as it would be in the narrowed 2 GHz BAS band. The envelope skirts are perfectly shaped and maintain their energy within the channel boundaries. In channel 2, an identical signal has been passed through a non-linear amplifier stage, adding significant spectral regrowth. The energy generated by this intermodulation process is spilling over the channel boundaries and will cause interference in both adjacent channels. ***No Receive filtering can prevent this from happening, since the interference is in the desired passband.*** If a 12 MHz channel were to be occupied by adjacent 6 MHz pedestals, the potential for problems would be greatly increased. There is the question of how to assure that a 6 MHz pedestal with a 3 MHz offset will meet the FCC emission mask for part 74.

The generation of IM3 products can only be controlled by careful design of the microwave amplifier stages in both the transmitter and in the receiver, and also by training operators to observe maximum output power limitations and receiver input levels. There is a natural tendency to run an ENG transmitter at full power at all times, and particularly when the going gets rough. In digital mode, more RF power is not always the answer, and in fact a power reduction may save the day.

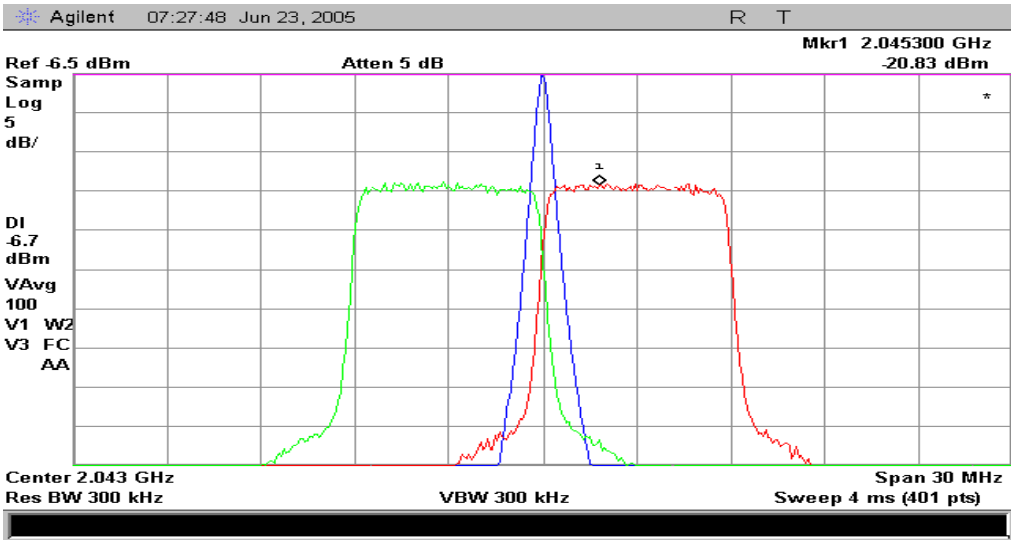

Figure 2 - Adjacent CodeRunner 2 Transmitters with 6 MHz COFDM pedestals

Figure 2 is an actual spectrum analyzer plot of two MRC CodeRunner 2 transmitters, running QPSK at 5.5 Watts in one 12 MHz channel. The shoulders of each 6 MHz envelope do not show any signs of broadening until they reach a point 45 dB below the mean power output (blue trace). However, when operated at full power in a 3.0 MHz offset mode, the slope crosses into the next channel between 25 and 30 dB below mean output, and does not be meet the FCC Part 74 BAS emission rules, which state:

> "74.637 (a)(2) When using transmissions employing digital modulation techniques:
> (i) For operating frequencies below 15 GHz, in any 4 kHz reference bandwidth (BREF), the center frequency of which is removed from the assigned frequency by more than 50 percent up to and including 250 percent of the authorized bandwidth: As specified by the following equation but in no event less than 50 decibels:
>
> A = 35 + 0.8 (G - 50) + 10 Log_{10} B (Attenuation greater than 80 decibels is not required.)
>
> Where:
> A = Attenuation (in decibels) below the mean output power level.
> G = Percent removed from the carrier frequency.
> B = Authorized bandwidth in megahertz."

Since the channel edge is exactly 50% of the total channel width away from the center, applying the formula provides the following result :

A = 35 + 0.8 (50-50) + 10log 12
A = 45.8 dB down from mean power output

However, the FCC rules state that the attenuation must be "in no event less than 50 decibels", therefore the acceptable value defaults to -50 dB at 6.0 MHz from the channel center, as referenced to mean power output.

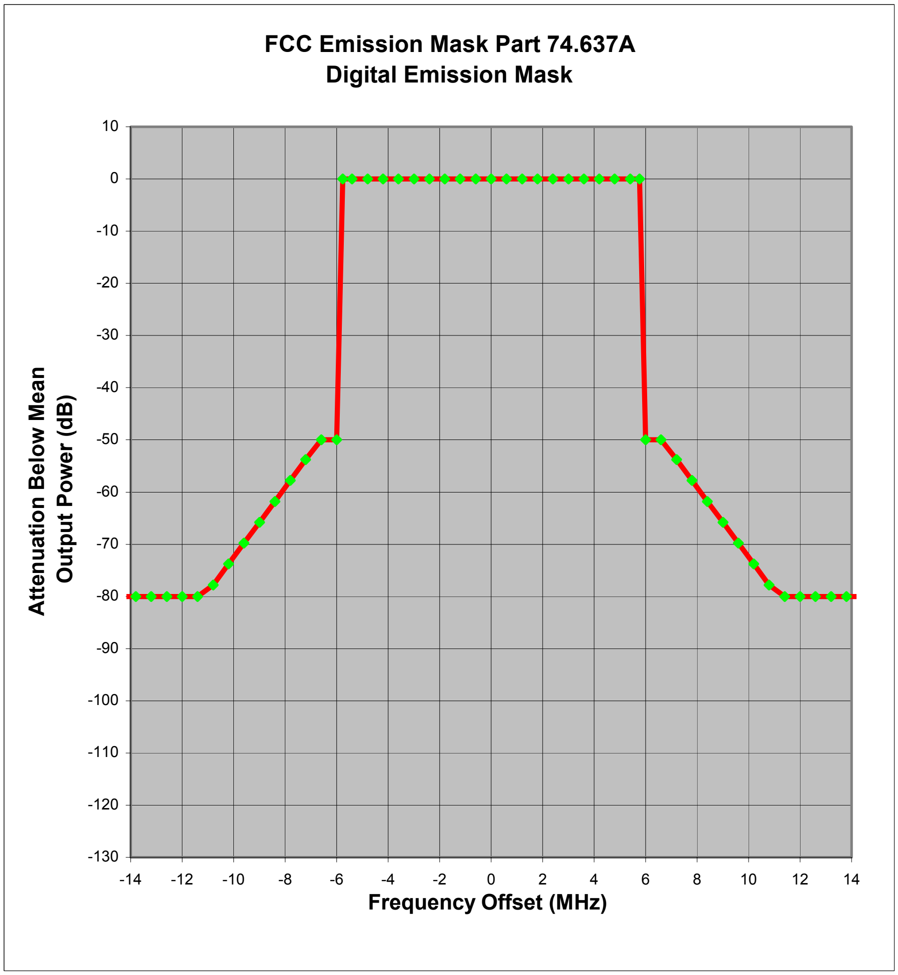

Figure 3 – FCC emission mask for Part 74 digital operation

With reference to the *theoretical* power spectrum density mask in ESTI EN 300 744V1.5.1 for DVB-T in the 2K carrier mode, the attenuation on the slope of a 6 MHz pedestal is in the range of –50 to –52dB below mean power output, which represents the best that anyone can expect under ideal lab conditions.

The best case, theoretical DVB-T power spectrum for a 6 MHz 2K-carrier pedestal operating at plus or minus 3.0 MHz from the center of a 12 MHz channel would just meet the FCC emission mask, with zero margin for regrowth, if operated at full power.

Knowing the best case theoretical limits, it is now clear that real world operation would require each transmitter to reduce its output power by 3 to 6 dB or more, regardless of who manufactured the radio. The RF power “back-off” factor depends on the total 3rd order intermodulation products, and the point at which the shoulders of the envelope begin to broaden.

Field Tests

A series of tests were performed in New York City to determine the practical reality of various COFDM pedestals and spacing in a real world environment. Care was taken to observe the FCC spectral mask requirements. The key results were:

a) Successful D-ENG shots from a location known to be "impossible" with analog modulation.
b) Maximum distances for ENG shots are in excess of 40 miles.
c) Near Field scenario; failure to disrupt a 25-mile shot even when a near TX (6 miles away) is at the high power setting on an adjacent channel.
d) Successful frequency re-use using both cross polarized 8 MHz pedestals and 2 x 6 MHz pedestals in a 12 MHz channel.
e) Sustained data rates >20 Mbps (i.e. – HD or greater quality) in a 6 MHz pedestal over a six mile path.
f) Simultaneous high and low adjacent test where performed and greeted with success, again confirming laboratory stated results.
g) Sustained manufacturer stated receive thresholds through out the 6 and 8 MHZ DVB-T tables from QPSK to 16 and 64 QAM settings

Conclusions

ENG channel offsets in the newly narrowed 2 GHz BAS band offer some potential for addressing crowded environments. Some have conducted lab tests to conclude that digital offsets will provide reasonable functionality. By virtue of our participation in actual field trials, we have verified that MRC BAS ENG radios are totally acceptable for digital offsets, however, there are a number of caveats that every engineer and operator must be aware of.

The most serious concern is with regard to the spectral emission mask as outlined in FCC 74.637. While it is clearly possible to meet the FCC mask, it will require each operator to change multiple parameters, including power level, when shifting to offset mode. Safe operating points can be established ahead of time with a spectrum analyzer, and memorized into the transmitter pre-sets.

From a frequency coordination standpoint, questions must be answered regarding individual C/I and T/I ratios for every specific radio that may be deployed in mobile and fixed link operation, and all applicable modulation formats, including single carrier and COFDM.

Over and above the FCC rules, the potential for success will be limited by factors at both ends of the path, a situation not typically present in split channel analog operation. Due to the potential for intermodulation products being developed by the transmitter, or at the receiver, a higher level of operating discipline will be needed. All of us at MRC are committed to providing the most flexible solutions available, and we are ready to help you tailor each system to your individual needs.