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IBOC results in three separate signals being broadcast from a single FM station. The analog signal will be broadcast as it always has been, and in addition to this signal, there are two additional digital radio signals broadcast. One of these identical signals is below the analog carrier frequency, and the other is above the analog carrier frequency. This system is similar to diversity reception using two antennas, but in the case of IBOC, the system uses two identical radiated signals. With IBOC, only one of these signals needs to be available at the receiver at any time for the system to work.

ERI was involved early on in this new technology when Lucent Technologies was in competition with USA Digital Radio, and we build five systems for Lucent's tests in various locations around the country. We were initially experimenting with 7 dB hybrids, and these were later replaced with ten dB hybrids to minimize the loss in the system. Later, when the Lucent and USA Digital Radio merged, we continued our work with iBiquity.

So, the big problem that needed to be solved for IBOC to work for manufacturers of FM antennas and filters was simply that of delivering isolation to the system. And, before going into antenna and filter applications to IBOC, I should mention that transmitters are available today that can produce both digital and analog signals using common mode amplification. The output of these transmitters can be fed into any side mount antenna with 400 KHz bandwidth or multiplexed antenna system with a constant impedance combiner demonstrating 400 KHz bandwidth. In the case of WNIN-FM operating on 88.3 MHz in Evansville, Indiana where I am a board member, we are purchasing a new common mode transmitter, and we will be radiating IBOC in late 2007. This is a great solution to the problem of adding IBOC to your NPR station if you are in the need of a new transmitter. WNIN-FM's transmitter is over thirty years old and is no longer manufactured, so this was an obvious move for us.

But, if your NPR station has decided to add an additional transmitter for digital only and add this to your system, you must consider how to isolate this new signal from your existing analog carrier. There are many different systems for you to consider with many different methods for achieving the isolation you need. I will now define some of these systems for your consideration.

IBOC broadcasting using a common antenna

The most straight forward method to use a common antenna to broadcast your IBOC signal is to use the existing antenna you have. This can be accomplished by using a ten dB hybrid to combine the analog and the digital carriers in the transmitter building. As I mentioned earlier, the ten dB hybrid is used to optimize the overall loss of power in the transmitter room. Basically, if you use a hybrid to combine your analog and digital carriers in the transmitter room, you will dissipate ten percent of the analog transmitter output and ninety percent of the digital transmitter output in a load in the transmitter room. So, you need to consider the heat load on the room air conditioner, the available output of the analog FM transmitter (it must have the needed

ten percent head room to accommodate the additional loss), and the cost of the digital transmitter. In addition to this, you must use a circulator with this system. As I'm sure that everyone knows, a circulator is a ferrite device that isolates a transmitter from a load. The circulator allows the transmitter output to go the load while the reflected power goes to a third port of the circulator where a dummy load is attached. Measurements on this system produce interesting observations because at the output of the circulator, one sees some of the coupled analog carrier, and on the input to the circulator, one sees only the digital output. At the output of the ten dB hybrid, however, one will see the composite analog and digital signal. The power levels in this system should be calculated rather than measured.

Dual input common antennas are available today, and these antennas utilize polarization diversity in order to isolate the analog and digital transmitters. These systems always use hybrids to produce the required isolation, and these hybrids (in this case, three dB hybrids are used) are usually installed up in the antenna aperture. In the case where the hybrid in located in the transmitter room (our ERI Cogwheel in Miami uses this technology), the antenna is fed with two feed lines. One feeds right hand CP while the other feed line feeds left hand CP. In most cases, the hybrid would be located in the antenna aperture, and the analog input would result in right hand CP while the digital input would result in left hand CP. Dual input antennas can be side mount single station antennas, side mount multiple station antennas, wrap around panel antennas, or top mounted antennas like the ERI COGWHEEL™ antennas in Chicago, Boston, Kansas City, Atlanta, Miami, Houston, and other locations. These antennas work quite well, but in both the single station cases and the multiple station cases, I strongly recommend the use of circulators on the outputs of all digital transmitters. The various frequencies that are added to these multi-station systems are usually combined in one of two ways. If constant impedance pass band combiners are used in the system, the digital input can be fed into the combiner into the normally used dump load port. This results in the digital carrier going one way in the filter feed toward what is normally the terminated port and the analog carrier going the other way. The two filter outputs are then fed into the analog and digital input ports of the dual input antenna. In our Miami system serving nine FM stations, the antenna input was split so that half of the analog went into the right hand CP input to the antenna with the corresponding digital signals for these stations fed into the left hand CP input port of the antenna. The other half of the stations had their analog feeding the left hand CP input to the antenna while their corresponding digital carriers were fed into the right hand CP antenna input. This system has the advantage of adding an additional 30 dB of isolation to the FM station transmitters by virtue of the antenna hybrid. Further, the feed lines are no longer phase critical which makes installation simpler. In the case of the ERI side mount DI antenna, the isolation, digital input match, and analog match are all independently adjustable. And, return losses of 40 dB for analog and digital in addition to isolations of 40 dB are possible with field adjustments. However, I always suggest that you think of the circulator as an inexpensive fuse for the digital transmitter in dual input (DI) antenna systems regardless of the measured isolation. The isolation is a function of the output matches of the antenna's hybrid, and these matches can change with ice and snow.

IBOC broadcasting using separate antennas

The use of separate antennas is also allowed. In this case, the separate antennas can be at the same location in an interleaved configuration, the antennas can be located one above the other (the analog antenna must be above the digital, and the digital antenna must be at least seventy percent of the height of the analog antenna and licensed as an auxiliary for the analog antenna), or the antennas can be located within three seconds of each other on separate towers. The separate antenna option has some very important advantages. For the interleaved case (ERI and all the other manufactures in the US offer interleaved arrays for digital and analog broadcasting), a circulator is a must. Different gain antennas can be used in this case, but care must be taken to make sure that the far field ratios are maintained and that near in interference between analog and digital doesn't become a problem. Using separate antennas that are not interleaved gives you the advantage of not needing a circulator for the digital transmitter. This is important. However, using separate antennas does require an engineering analysis in order to determine the required digital transmitter power. And, when these systems are installed, field measurements can not be used to specify the digital power lever. Rather, it must be calculated based on the coverage analysis from the two separate antennas.

Summary

In planning your digital future, you have many decisions to make. The advantage of using the same antenna radiating elements for both analog and digital is that you end up with roughly the same horizontal pattern for analog and digital as well as the same elevation patterns for both analog and digital. In an urban area, this is a significant advantage. Using separate antennas (interspersed, at different heights, or on different towers) gives you the advantage of having an auxiliary antenna to use in an emergency. Using a common mode transmitter eliminates the need for a circulator and a separate antenna. Using a ten dB hybrid makes the digital transmitter cost go up and adds loss to the transmitter building, but it does allow you to use your current antenna. If this option is used, I suggest matching the antenna in the field to make sure that you have the best bandwidth and match for the analog and digital signals.

In that last five years, ERI has designed, built, and installed many DI systems. We have installed single station side mount DI antennas all over the US, and in the case on our DI in Indianapolis, I had the opportunity to personally do the field match of the antenna. I ended up with 40 dB matches on both analog and digital along with an isolation of 50 dB between analog and digital. We have ERI broad band dual input antennas in Chicago, Kansas City, Atlanta, Miami, Houston, Boston, Seattle, and many other locations. Our most recent system was installed in Houston, Texas where we have nine full class C FM stations with analog and digital feeding one antenna. These multiplex systems have typical input VSWR values of 1.08:1 and isolation numbers in the 30 dB range. In New York City, we have three dual input antennas on the Empire State Building, and most of the FM analog and digital service for that market is broadcast on ERI hardware.

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