R/C RECEIVER PERFORMANCE CONSIDERATIONS

SO WHAT IS THIS PAPER ABOUT?

People want to know what the difference is between single conversion and dual conversion receivers and their performance. Dual conversion receivers in R/C were rare up until the 1980s, but have become commonplace today

A. IS THERE A PROBLEM WITH SINGLE CONVERSION (SC)?

There is one situation where a single conversion receiver is open to interference that a dual conversion is not and that is at image frequency.

B. WHEN WILL SC BE BOTHERED?

The one situation where a single conversion receiver gets hit is when a bunch of totally undisciplined flyers have a meet. What I see at glider meets is a guy who finds a breath of lift. Like fisherman when they see another guy catching fish, the rest of the flyers rush over and stand shoulder to shoulder by the guy to get the same lift. If you looked at the resulting spectrum on a spectrum analyzer, you would be appalled to see what happens to the spectrum when they do that Intermod signals reach far beyond the upper and lower end of any of our bands, right out to and well beyond the Image frequency of any single conversion receiver. The solution is so simple; just keep a reasonable separation between transmitters. This intermod doesn't hit a dual conversion receiver because the image is at least 21.4 MHz away from the transmitted frequency.

B. WHAT IS DUAL CONVERSION ALL ABOUT?

The IF for Dual Conversion (DC) model receivers has always been 10.7 MHz which means the receivers have image rejection of 60 db or better. Model receivers for over 30 years have been "Superheterodyne " receivers. It is very difficult to have good selectivity at RF frequencies. It is not impossible: a monolithic crystal filter (MCF) at the transmitted frequency can be used. FMA designed an AM and an FM version of an MCF receiver in the early 1990s.

Since we can't readily get narrow band at RF, the concept of heterodyning takes place. You will be most familiar with this when you listen to twin engines running. The two run at almost the same rpm, but not exactly and you hear a third frequency drumming away that is called a "beat frequency". We do this same thing in a receiver in a stage called a mixer. Two frequencies of interest enter the mixer. The first is the transmitted RF frequency. The second comes from a circuit called the Local Oscillator(LO) in the receiver. The LO runs at a frequency removed from the incoming RF signal by the amount called the Intermediate Frequency(IF). The standard for some 50 years of radio was 455 Kilohertz (KHz). The output from the mixer is a spectrum of four resulting signals: the sum of the RF and LO; the RF ; the LO; and the difference between RF and LO. The sum and the difference are the heterodyned signal; heterodyning means to beat the two signals together to form a new frequency. We want only the difference signal, in this case, 455KHz. The other signals are generally passed through a low pass filter that suppresses them and allows the much lower IF to pass into the IF section of the receiver.

Now, we can operate on the IF signal to narrow the spectrum that will pass so we get good adjacent channel rejection. For 50 or so years, the primary IF device was an IF transformer that combines inductance and capacitance to form a "band pass filter" that lets the IF frequency through, while suppressing other, unwanted signals. However, there was always one form of interference that the IF could not stop. It can't tell where the signal at 455KHz is coming from. If you run a signal that is 2X455 KHz from the RF signal, the mixer creates another signal at 455 KHz called the image frequency. The only suppression of that signal is the band pass filter that forms the antenna input filter. Suppression of a signal only 455 KHz away from center is almost nil, so a SC receiver responds about the same at image as it does on frequency. It also offers very little suppression of the LO signal to prevent it from radiating out the antenna and that is why the SC receiver has trouble meeting FCC requirements for unintentional radiation. Until recently, Image has never been a big problem for RC as long as the LO is designed to operate outside the RC band of interest. The 72 MHz band uniquely spans 1 MHz; enough that image could be at another 72 MHz channel unless you put the LO on the high side for the upper half of the band and vice versa.

The 455KHz IF has always been convenient because transformer and, more recently, ceramic filters at that frequency are readily available and inexpensive. You can, in fact, use any IF you want if you want to design and build your own IF filter. Many of the cellular phones use a 40 MHz first IF. You can even have an IF at a higher freq than the RF. One manufacturer offers a unique FM chip that uses a 100 KHz IF and that is low enough to permit the use of a circuit that is called an active filter in the chip. Selectivity is excellent with the active filter, but you have to do something about the image!

The DC receiver gets rid of the image frequency as a problem. While LC filters in the front end offer little attenuation for signals only 455 KHz out, they do very much better as the frequency of the first IF is increased. Most model receivers use dual conversion so that we can take advantage of easier amplification and band pass filtering; both more difficult at even 10.7 Mhz. Now, we can have both excellent image rejection and excellent adjacent channel rejection. Most personal communication receivers such as produced by Motorola, Ericson and others use a single IF at 10.7 or 21.4 MHz. However, board size and weight are not a consideration there. Up to now, we R/C receiver designers have been stuck with lower Ifs and DC to keep down weight, cost, and size.

D. ANOTHER GREMLIN LURKS ABOUT

Although it has nothing to do with SC or DC or what IF frequency you design with, there is one other design criteria that it would be shameless not to cover while writing this. That is Third Order Intermodulation also called Intermodulation Distortion (IMD). We shortened it to a small mouth full in the AMA Frequency Committee by referring to 3OIP(Third Order Intermodulation Products). 3OIP is specified in Db above a milliwatt(dBm). It is a function of the type mixer used in the receiver. However, it is also a product when any RF or audio amplification takes place, such as in an RF amplifier in the front end of a receiver, or, as we will discuss later, an RF amplifier in a transmitter. 3IM also exists very strongly in audio equipment where you can really sense distortion.

3OIP occurs when three signals enter the receiver mixer, which occurs every time you fly with more than one other modeler. If a receiver has poor 3OIP, it will be subject to interference whenever you have the adjacent channel to yours, plus the second channel out in operation. Since our frequencies are 20 KHz apart and evenly spaced, this phenomenon can occur with any combination of three transmitters. That is, you receiver mixes all three and the heterodyne of the mix can be within the bandpass of the receiver and can interfere. For example; the 2nd channel out and the fourth; the fourth and the eighth; etc. A poor mixer such as a standard transistor has very poor 3OIP. In the 1980s when I developed and wrote the Guidelines for the Design of R/C Equipment in behalf of AMA, I conducted extensive research that characterized the type devices available for mixers. We checked bipolar transistors, FETS, active double balanced mixers; dual gate FETS; and passive mixers. The passive double balanced mixer was by far the best. We have continued to refine receiver designs built around the passive DBM up to the point that FMA now uses a proprietary passive DBM that is manufactured for us here in the US in a tiny SMT package. We pay more for our mixer than some folks pay for all the components in a receiver! But it is worth it; we get phenomenal receiver performance and no one ever reports interference with our DC receiver.

C. AND ONE LAST FLY IN THE OINTMENT

Transmitter RF amplifiers also produce intermodulation distortion that is very strong. Few are aware of it. Perhaps a little enlightenment will help reduce the problems that go with it. When three transmitters operate near each other, the signals from each enters the other two via the antenna; are mixed in the output amp just like a mixer in a receiver; and the composite signal, including all intermods, is amplified and transmitted. This is bad enough when you have just three. When you get eight, ten, or more transmitters operating in close proximity, the composite spectrum truly fills the screen on a spectrum analyzer. The closer the transmitters are to each other, the worse it gets. Moving one antenna can change the spectrum instantly. The resulting IM spectrum, when viewed on a spectrum analyzer, reaches well beyond the image for an SC receiver, but is suppressed sufficiently by a DC receiver to avoid problems. The AMA frequency committee established guidelines that generally prevent this problem. If you keep the transmitters separated by about three wavelengths, 3IM between them is no problem. That is the way AMA has specified that flying sites should operate. However, certain groups ignore the guidelines and then complain that equipment receives interference. The solutions are well known: either use the AMA Guideline separation of stations or stick with a dual conversion receiver.