How-to: Debugging a Low-Powered RF Transmitter

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We were recently commissioned to redesign a remote control transceiver operating in the 902-928 MHz license-free US band. The client had an operable unit, but its output spectrum was so ugly that the possibility of passing FCC certification testing was nil.

The original board had been layed out by a competent PCB engineer but he was not knowledgeable about RF layout issues. There was little in the way of ground planes, no via grids to connect a top and bottom ground pours to the inner ground plane, no controlled impedance traces, etc.

We addressed these and other problems by re-laying the board, taking good RF performance into account. Soon we had the revised board in our hands, populated and ready to check out.

The firmware in one of the boards was set to make the board continuously transmit at a frequency in the middle of the band. This allowed us to easily verify the spectral purity and power of the RF output signal. By replacing the normally soldered monopole antenna with a short section of micro co-ax (I like to use Digikey part number 229-1007 along with an SMA adapter) we were able to measure the output power into 50 ohms by simply connecting the co-ax to the input of a spectrum analyzer.

This is where the fun started! The power was low --- way too low. The transmitter had been designed for an output power of about +20 dBm or 100 mW but we were only seeing about +6 dBm or 4 mW. So where does one start to see why the power output is so low in a situation like this?

The first thing we noted was the power supply current. It was what we would expect for full power operation, so we were convinced that the power was being generated - it was just not making its way to the antenna connection.

Next we isolated the RF output stage-by-stage. We connected more of the micro co-ax to various spots in the output chain, starting with the output of the RF integrated circuit. We were careful to break the connection to the next stage by removing a coupling component, such as a coupling capacitor. We were also careful to be sure that there wasn't a DC path to ground on our output tap. We would then fire up the transmitter with our tap connected to the input of the spectrum analyzer and measure the output power.

Debugging a board in the lab

This particular transceiver consisted of an RF integrated circuit, SAW filter, RF power amplifier, transmit / receive switch, and a discrete component L-C low-pass filter. We moved the micro co-ax tap to the output of each of these stages to check the output power levels. Everything looked fine; even the output of the T/R switch was well over +20 dBm. This focused our attention on the L-C filter since the power was fine ahead of it but lousy after it.

We placed micro co-ax on the input and output sides of the L-C filter so that we could measure its frequency response and insertion loss. We used a sweeped frequency signal generator for this test, since our spectrum analyzer with the internal tracking generator was in use on a different project.

This rapidly showed that the filter, which was supposed to have a 950 MHz 3dB cut-off, had a 600 MHz cut-off instead! We changed the values of a couple of inductors and one capacitor and we got the sort of low-pass response that we were expecting.

We removed all of the micro-coax (except for the output connection), replaced the coupling capacitors, and turned the transmitter on. The output was now just what it should have been and the spectrum looked nice and clean.

The time from first power to good output power was only a couple of hours.