

TESTING THE EFFECTS OF M-CODE ON GPS TIMING RECEIVERS

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Abstract

The Naval Research Laboratory has measured the effects of several modulation schemes proposed for use as the new Global Positioning System (GPS) M-Code on the operation of existing GPS timing receivers. Three candidate codes were tested at varying power levels to quantify the effects of the new signal added to a traditional GPS signal generated by a 10-channel GPS signal simulator. The M-Codes were generated in hardware to make representative Binary Offset Carrier and Manchester waveforms. Because the new codes may be run at considerably higher power levels than the current C/A and Y code signals, the M-Code signals were added in at power levels up to 40 dB over the existing signals. The test results show that the presence of M-Code signals is detectable. The effects on noise in the pseudorange and timing outputs are small.

INTRODUCTION

GPS Modernization will include a new waveform, M-Code. M-Code is for military users and is designed to be a more robust and more usable signal than the present P/Y-Code in current use. As of the writing of this paper, the final waveform had not been announced. The candidate waveforms all share the property of putting the signal energy in the nulls of the current Y-Code signal. Like the current Y-Code signal, M-Code is only for authorized users and will not be available to the general public or the time-transfer community outside of the military. The issue for the non-military user is the effect of a strong new signal on the C/A code and carrier signals in existing GPS time transfer receivers. Since M-Code is to be more jam-resistant than P/Y-Code, it is likely that it will be considerably stronger than the current signals. GPS receivers have a relatively small dynamic range on input signal levels and could be vulnerable to interference.

This paper describes testing done at NRL to determine the likely effects of the new signals on time-transfer receivers. Three receivers were tested, two geodetic-quality receivers often used for timing and one commercial timing receiver.

M-CODE

M-Code is a new signal modulation designed to provide enhanced capability for military users of GPS. Figure 1 shows the current GPS signal spectrum and how the new signal will fit in. Currently the GPS L1 frequency (1575.42 MHz) has two signals modulated on it, C/A-Code and P/Y-Code. The spectra of these modulations are characterized by a strong central peak surrounded by deep nulls at the modulation chip rate and its multiples. For C/A code the chip rate is 1.023 MHz and for P/Y-Code the chip rate is 10.23 MHz. The GPS L2 frequency (1227.6 MHz) is similar, but currently has only P/Y-Code modulation. In the future, L2 will include a C/A-Code signal to allow civil use of the frequency. M-Code is a split-spectrum signal with little energy at the carrier frequency and major lobes spaced away from the carrier. These side peaks in the modulation spectrum are intentionally put in nulls of the P/Y-Code. This has the benefit of minimizing interference between the new signal and the old ones. It also is specifically designed to keep the military signal energy away from the civil C/A-Code signal.

To improve the performance for military users in a jamming environment, the M-Code signal will likely be able to operate at powers 10s of dB higher than the current signals. The exact nature of signal was still in development at the time of the paper, but enough is known about it to be able to simulate its spectrum over a range of power levels.

NRL TEST APPROACH

NRL designed and built a M-Code spectrum generator capable of making a noise spectrum similar to that made by two families of candidate waveforms, Binary Offset Carrier (BOC) and Manchester. These waveforms are not identical to the final waveforms in that they are not generated from a secure spreading function and do not contain any navigation data. The intent was simply to put energy in the appropriate part of the spectrum. Figure 2 is simplified block diagram of the generator. Spectrum plots for Manchester and BOC codes are shown in Figures 3 and 4 respectively. It is capable of being clocked at rates up to about 11 MHz. The M-Code energy is added to the GPS signal from a GPS signal simulator. The test configuration, Figure 5, includes the ability to add white noise to the signal to simulate the noise in a real receiver from ambient noise and preamplifier noise. Levels from each source are individually adjustable and up to four receivers can be tested simultaneously.

The test scenarios were all based on a fixed position case using a nominal GPS constellation of 24 satellites. In each case the scenario starts with a period of nominal operation to allow the receiver to achieve lock and stabilize. The M-Code power is then increased in 2 dB steps up to a level of 60 dB above the C/A-Code power.

The observables in the experiment were carrier-to-noise (C/N), number of satellites in track, receiver lock status, 1 PPS output, and the position solution. These parameters give a clear view into the state of health of the receiver. The signal to noise parameter provides a strong indication of the presence of noise in the signal channels. The other status indicators degrade as signal to noise deteriorates, eventually resulting in a loss of lock. The 1 PPS output of the commercial timing receiver was compared to the simulator reference tick. For the geodetic receivers, the 1 PPS output is not a good health indicator, so the position solution is used to determine the quality of the received signal.

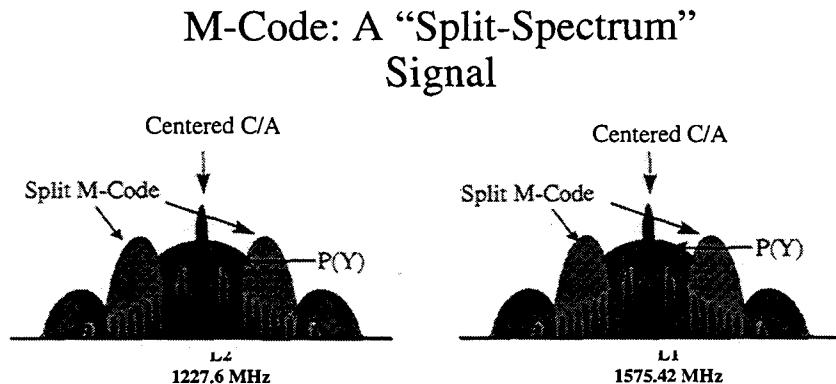
RESULTS

The primary finding of this experiment is that none of the receivers tested were significantly affected by the presence of M-Code at levels of 20 dB above the current GPS signals. In fact, all of the receivers were still operating at near normal performance with the M-Code noise at 30 dB above C/A-Code. One of the geodetic receivers was still tracking at a level of +60 dB.

Figure 6 shows the signal-to-noise level for the commercial timing receiver, which uses an older Trimble GPS engine. The -130 dBm level is the initial settling period for the receiver. The power is stepped up 20 dB and then increase in 2 db steps. The C/N characteristic is typical of all the receivers tested. This unit lost all satellites at +52 dB. The time offset of the 1PPS output of this receiver, Figure 7, shows an initial pull-in followed by a period of unperturbed performance up to the point where the receiver lost lock on GPS altogether. The number of satellites in track for each receiver was essentially unchanged up to the point where the receiver began to lose lock on all channels at once. The change from tracking all satellites to none was a sharp transition. Similarly, the position solution on the geodetic receivers changed little up to the point where no new positions were generated.

CONCLUSIONS

M-Code should not be a major concern for the GPS timing community. Power increases of up to 30 dB have little effect on existing time-transfer receivers. Other aspects of GPS Modernization, such as the addition of C/A-Code on the L2 frequency, will actually improve performance by giving direct access to ionospheric correction data.



Identical Signal Structure at L1 and L2
Centered-C/A on L2
Split-M code on L1 and L2
New, centered civil signal at 1176.42 MHz

Source: GPS Joint Program Office

Figure 1

M-Code Generator

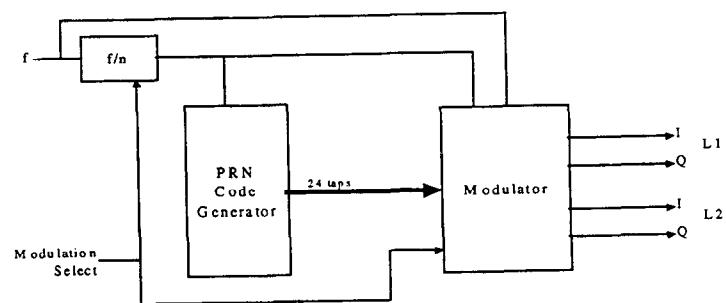


Figure 2

Manchester 8,4 Waveform

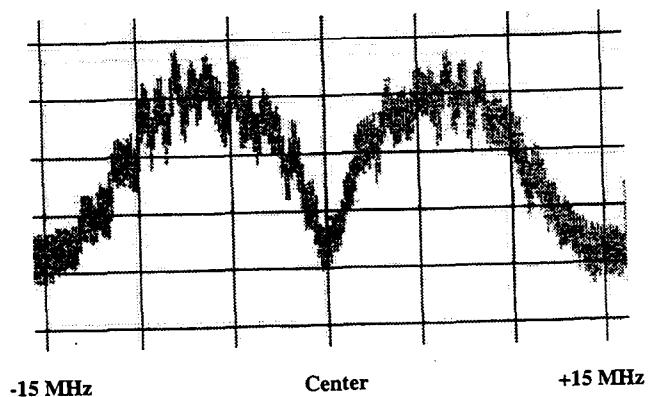


Figure 3

BOC 10 Waveform

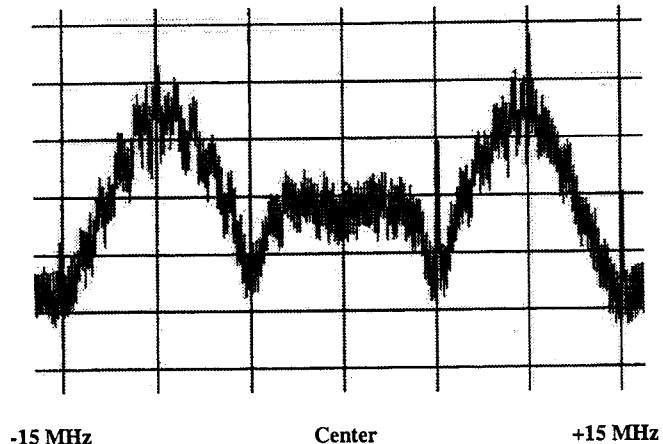


Figure 4

Block Diagram

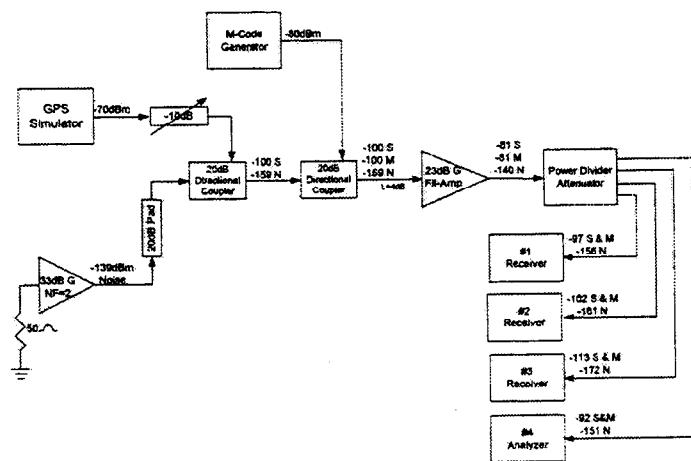


Figure 5

Signal Level Effects

Manchester 8 Code

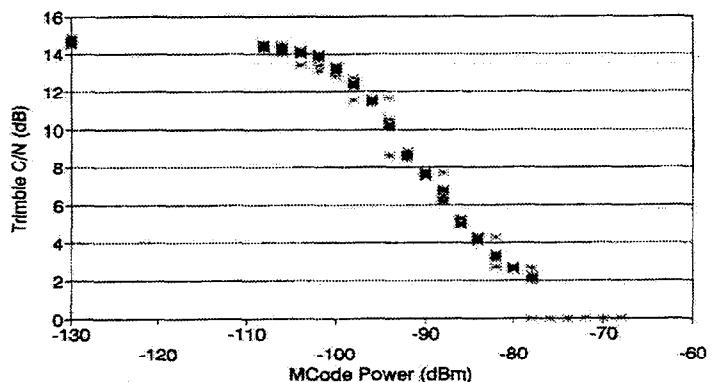


Figure 6

Timing Receiver 1 PPS

Manchester 8 Code

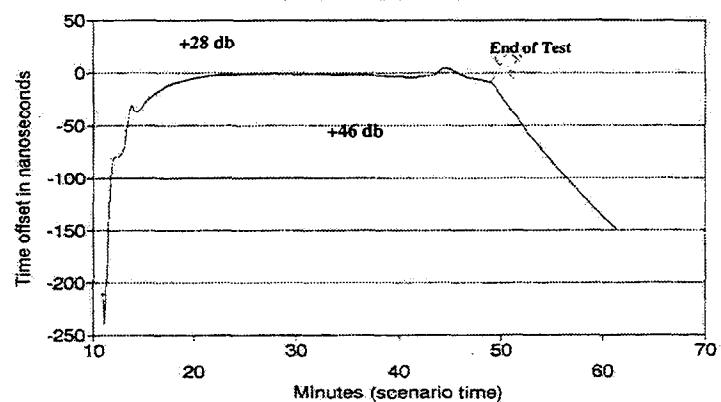


Figure 7

Questions and Answers

SAM STEIN (Timing Solutions): Joe, I believe that some pseudo-like designs are also using the nulls in the P-code spectrum. Do you expect more interference with the M-code?

JOE WHITE (NRL): I really don't know, Sam. I don't know too much about that. You may have a better feel for it than I do. But if they are using the same kind of spectrum, I would assume the results are going to be very similar. The thing that we saw -- I mentioned we tested three different wave forms. I showed you the results on one. But the results were almost identical in all the waveforms; they were within a dB or two of the same numbers. So again, if somebody does something similar, I wouldn't expect a big problem. I guess if I were they, I'd be a little bit concerned about having M-code on top of me, though. I haven't tested for it specifically and I don't have a feel for it.