GLOBAL POSITIONING SYSTEM TELECOMMAND LINK

Daniel F. Alves, Jr.
Alpha Instrumentation and Information Management
896 Blake St.
Santa Maria CA 93455-4955

ABSTRACT

The Global Positioning System of satellites and pseudosatellite ground stations (GPS) is designed to provide very accurate Time, Space, and Position Information throughout the entire world. It is also being used to provide such information to unmanned vehicles operating on test ranges throughout the United States, as a replacement/ adjunct for tracking radar as well as a form of guidance. What is proposed in this paper, for which a patent has been applied, is that the existing L-Band RF link carry command information, when required, as well as TSPI information. Key Words: Telecommand, GPS, Range Applications, TSPI.

INTRODUCTION

Almost all unmanned aerial vehicles, including rockets and missiles, have some sort of command receiver on board for reasons of range safety or for remote control. At present, telecommand information to such receivers is normally provided through dedicated radio frequency links. Typically, telecommand is accomplished by way of a dedicated UHF channel located between 406 MHZ and 549 MHZ, with the commands themselves taking the form of frequency modulated audio tone pairs. Each range is provided its own frequency (or frequencies) so as not to interfere with other ranges. For instance, the Eastern and Western Test Ranges have been assigned 416.5 MHZ for a primary frequency and 406.5 MHZ for a secondary frequency, White Sands Missile Range has been assigned 409 MHZ and the Pacific Missile Test Center telecommands on 425 MHZ. What this means is that any program which requires telecommand support cannot easily be moved among ranges. Command receivers have to be retuned to work on different ranges and there is effectively no easy way for a vehicle to fly through more than one range during any one operation. Essentially one range must be prime and the other range's telecommand assets must be retuned, something that cannot be done in real time.

Additionally, the frequency band is not dedicated to this function. While 406.5 MHZ to 420 MHZ are dedicated to flight termination, the entire band is assigned to many other users, Government and private. For instance, the SARSAT ELT frequency is 406 MHZ, amateur communications can be found between 420 MHZ and 450 MHZ, and UHF channel 14 begins at 450 MHZ. At the present time telecommand exists in this band on a waiver which will expire in 1995.

The GPS Navigation Message is designed to provide users with enough information, or data, to use the satellite constellation to determine user location. But data transmission is one thing, command transmission is another. In the case of data transmission, one strives for high data rates, with acceptably low data dropout rates, of course, in order to transfer the maximum of intelligence in the shortest time. The emphasis is on higher and higher data rates. In the case of telecommand, command messages are purposely kept short and simple. That is, the information content, or data, as it were, is the minimum possible to effect the desired output, which is usually a voltage on a particular connector pin. The emphasis is on reliability, so the information transfer rate is purposely kept as low as possible. This is a major difference between data and command messages.

GPS TELECOMMAND

What is proposed is a new use for GPS which will in no way impact the use of the GPS by its other users, and that use is telecommand. There are three major cases whereby telecommand can be accomplished and which are covered in the patent application. Each of these three cases calls for the addition of some componentry and/or software to existing range applications designs, both on the transmission and reception ends. The figures provided in this paper illustrate only the reception end; the transmission end will necessitate appropriate “Mirror Image” additions.

In the first case, (see Figure 1) the telecommand signal is sent as a direct spread (DS) signal, utilizing a Gold (or similar) Code as a spreading modulator and sent at the L1 frequency (1575.42 MHZ) used by the GPS C/A signal. This signal would look like a GPS C/A signal, except that the DS spreading code, while being similar to a proper C/A Gold Code, would not be a code assigned to any GPS NAVSTAR satellite. The additional circuitry shown in Figure 1 is basically identical to what might be found in a GPS receiver because the telecommand link is in the form of a GPS signal. The “data” contained in the message which would be demodulated from the output of the additional correlator would not be data at all, but commands. For ease in fabrication, the form of the command message could be in the same form as the GPS data message, e.g. 50bps BPSK. It does not have to be in any particular format, however. The commands could be in the existing IRIG audio tone-pair format or the so-called secure High Alphabet tone-pair system used by the Space Shuttle. By abandoning the present UHF Telecommand system, however, an updated digital command message format could be developed, incorporating more modern techniques to enhance intelligibility under all circumstances. Of course, adoption of this approach to telecommand is not necessary to effect such a change but, by replacing the existing system in its entirety, it does make such a course of action much more feasible, as there would be no compatibility requirements with the existing system.

To discriminate between several vehicles in flight at the same time, different DS codes could be used, assigning one DS code uniquely to one vehicle. Alternatively the command messages could be assigned uniquely to each vehicle. Both tone-pair systems allow for alternate commands, although the IRIG standard system is very limited. Another possible option for discrimination is to use L2 (1227.6MHz) for s second vehicle. Indeed, to guarantee a true dual flight termination system with no single-point failures, both L1 and L2 could be used simultaneously to two receivers installed in the same vehicle, sacrificing frequency-based differentiation for redundancy.

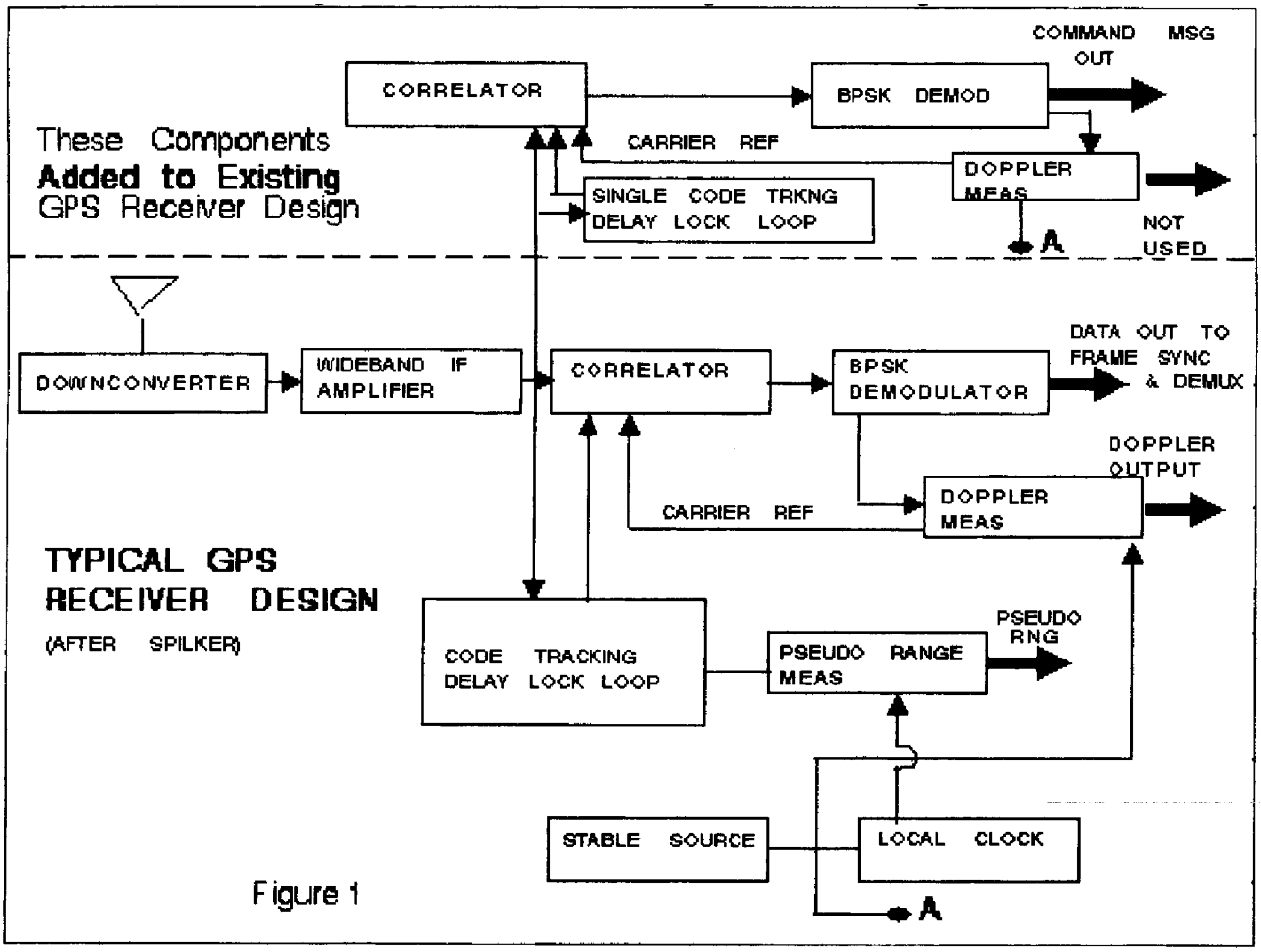

Figure 1

The coded, spread spectrum signal approach could also be done as an analog to the P-code navigation signal. All functions would be the same as the C/A-code lookalike case with handover and lock-up on a P-code lookalike. There isn’t much utility in this approach, however, as the time to transmit the command information is lengthened and usually the transmittal of commands calls for the shortest time possible to be spent from initiation of the command to its execution. Using such an approach on a missile or space launch vehicle, where the shortest possible time delay is very important and flight time is on the order of minutes, the receiver could be “captured” prior to launch by sending the “IC/A-like” code and transmitting a null command message, spending the search and synchronize time on the ground.

If a translator is used onboard the vehicle, as is most likely, the command recognition and processing circuitry must be incorporated into the design. It will resemble a single channel GPS receiver except that the correlator will only be programmed to recognize one DS code; the code assigned for telecommand usage. Such circuitry now exists in sizes of less than ten cubic inches.

The transmission system can be a special purpose transmitter which resembles a pseudosatellite, or a true pseudosatellite ground station with command capability as an added feature. It is also conceivable that future GPS NAVSTAR satellites might incorporate the capability of relaying telecommand signals. This would call for the capability to transmit different DS spreading on command.

The second case, (see Figure 2) is simpler and faster-acting. Here the command information is sent on a single frequency signal which is NOT modulated by a spreading code. The additional hardware required is no longer a direct spread correlator, but a simple detector which feeds a demodulator. As in the first case, the form of modulation taken by the telecommand link is not important and could be FM, AM or PM, for instance, and, as above, the form of the command message is also not important. The radio frequency of operation can be either L1 or L2. As a spread signal is not used, this case reduces the time delay from initiation of the command to its execution, as there is no time lost in acquiring and "locking up" on the spreading code in the correlator.

For this case the ground command station or transmitter site will broadcast on L1 and/or L2 at high power to effect capture of the receiver. This would be necessary to prevent an unauthorized command from entering the receiver and is the primary technique used in today's telecommand systems. This is not necessary in the first case because the use of pseudorandom noise (PRN) codes and spread-spectrum modulation techniques provide this protection.

The third case, (see Figure 3) is based on defining or redefining portions of the present GPS Navigation Message. There are four non information-bearing bits in the GPS telemetry stream. By utilizing these four bits, two in the TLM word and two in the HOW word, it is possible to transmit a command through the existing GPS NAVSTAR satellite network

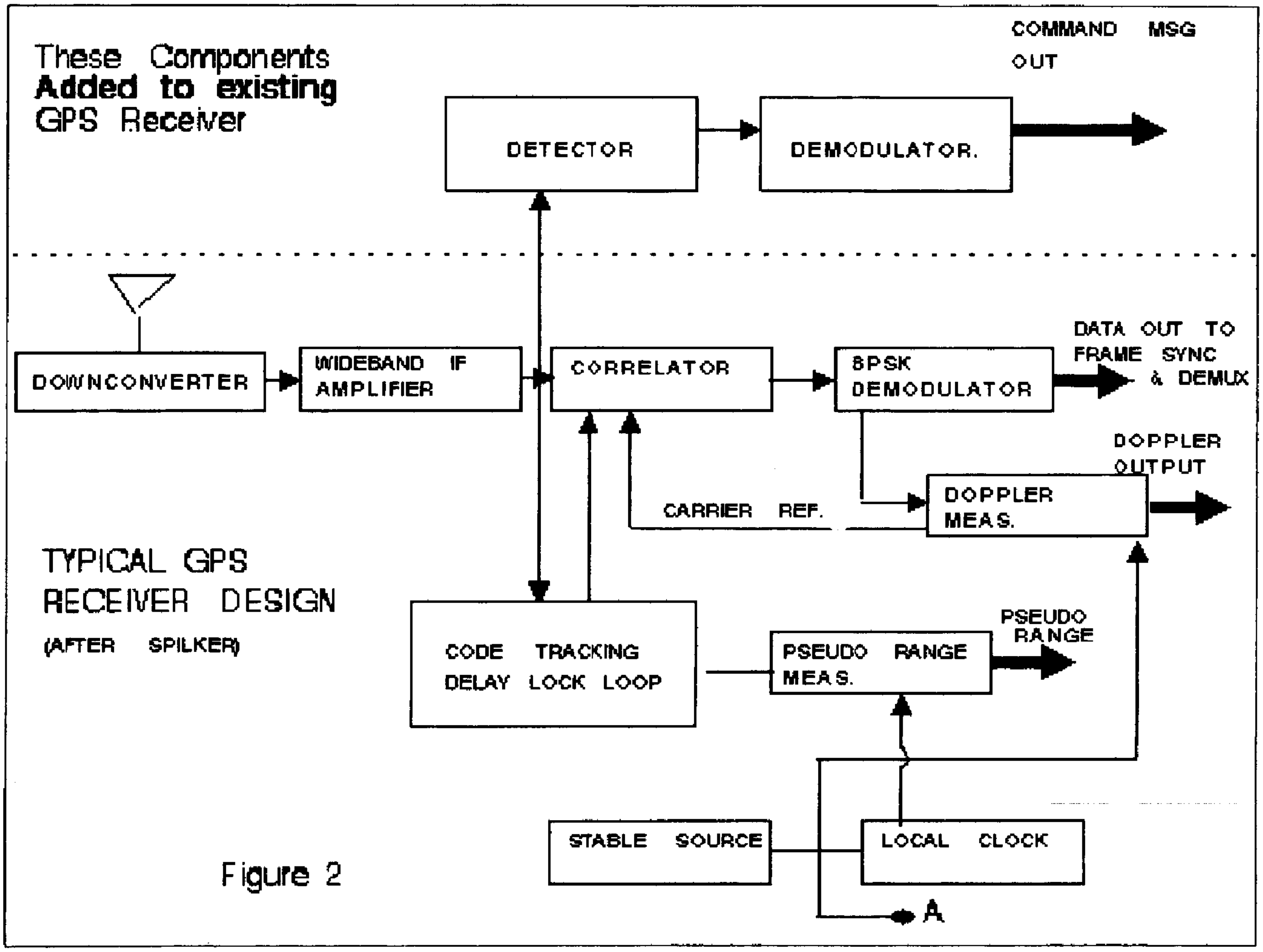

Figure 2

with minimum modification, thus allowing a global telecommand capability. These bits are picked because these two words occur at the beginning of each subframe, thus limiting the internal delay to a maximum of 6 seconds, which is the length of time to transmit one subframe. If other bits within the Data Blocks of the GPS navigation message were picked, the internal delay could be as great as 30 seconds, probably too great a delay for most telecommand situations. It has been mentioned in the literature that these non information-bearing bits might some day be used to transmit data, nowhere in the literature is there any reference to these bits, or any other bits in the GPS navigation message, for that matter, being used to convey commands.

Alternatively, The TLM or the HOW word can be changed to either serve as a flag that the rest of the incoming message is not a Navigation Message but is a command, or such a changed TLM or HOW word could also incorporate the command.

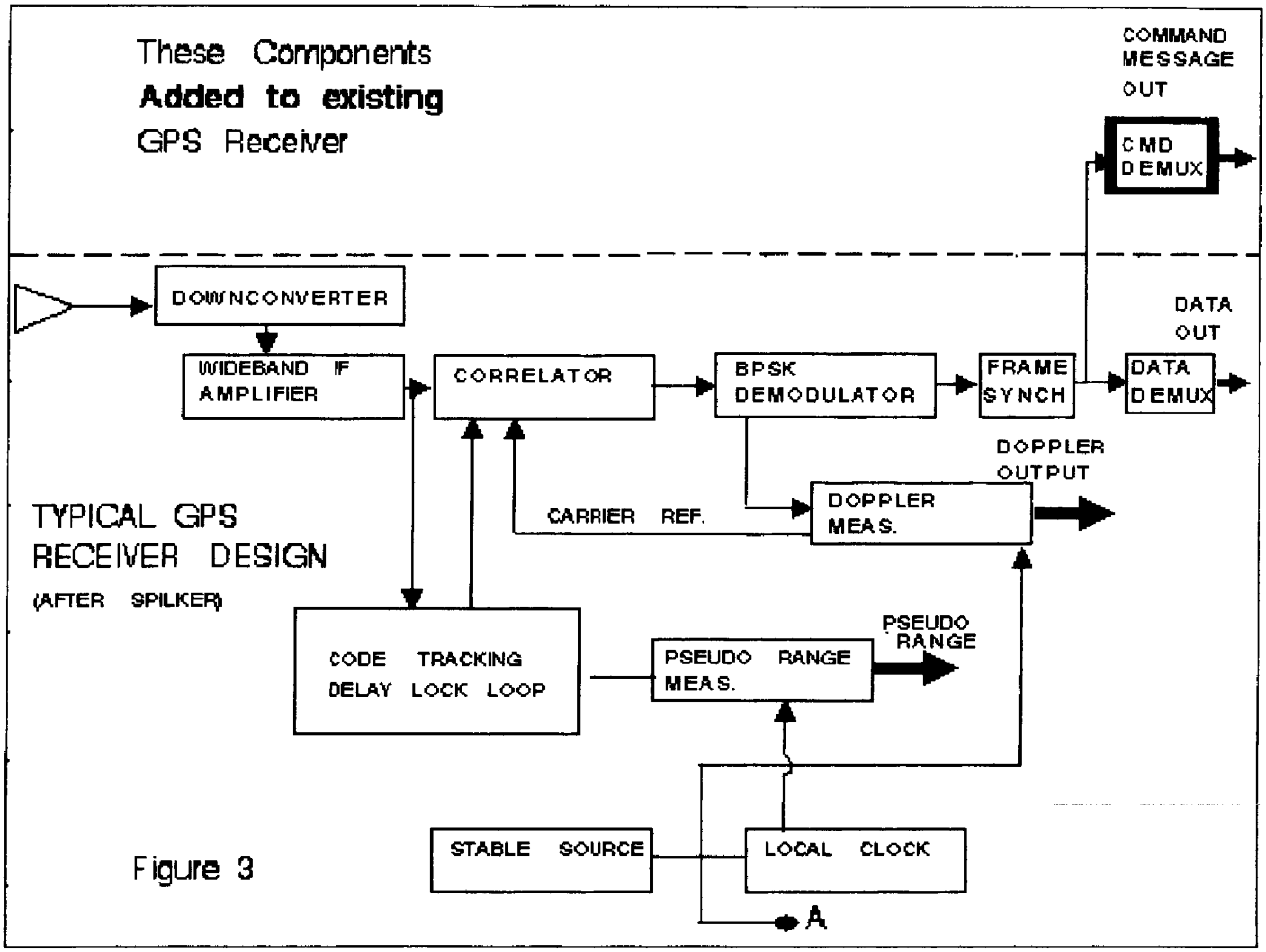

Figure 3

This would not be quite the same as discussed above as this would call for actually redefining the bits in these words as opposed to giving a definition to the four non information-bearing bits. This approach may be necessary if there is a need for more commands than can be handled by four bits.

As can be seen, this case can be implemented with software only and need not call for any additional componentry - except in the case of a translator, where a single channel GPS receiver must be incorporated to decode and process the command message. As was discussed earlier, such circuitry is of minimal size, weight, and power consumption.

ADVANTAGES

As discussed in the Introduction, the UHF band is crowded and telecommand exists in this band under a waiver. By using an integrated GPS TSPI/Telecommand system, not only is telecommand moved out of the 406MHz to 549MHz band but no new bandwidth is needed for telecommand. The existing L1 and L2 frequencies used by GPS receive additional usage without compromising their use as a TSPI source. This is all due to the nature of spread spectrum, which is an integral part of GPS architecture.

Advantages of the proposed approach, stem not only from the ability to establish a potentially universally compatible telecommand capability at the Test and Training Ranges, away from the seriously crowded UHF band traditionally used, but also in the redesign of the actual command messages. For instance, there is a DOD policy which mandates the use of secure telecommands for flight termination of missiles. This is to preclude unauthorized commanding of flight termination or jamming of the command and is the reason the Titan IV SLV uses the Space Shuttle secure High Alphabet system of commands. By being freed from the existing UHF system, and its specified audio tone format, the command message can be designed to be easily encrypted. In the first and third cases, the use of DS modulation, which is central to GPS architecture, significantly improves the protection afforded the command.

It would also be possible to have a selective command/all command, or a command/insure command mode by transmitting command information by spread spectrum (to individual units by using separate PRN codes) and also by broadcasting on the L1 and/or L2 frequencies thereby being received and processed by all units. Again, the additional componentry/ software necessary to implement such an option would be minimal.

A Global Positioning System telecommand link provides other important advantages besides the flexibility that a new system of telecommanding can grant and the opportunity to move out of the somewhat crowded UHF band. Existing methods of providing TSPI information and commands consist of separate systems calling for duplicate radio instrumentation aboard the unmanned vehicle. There are separate antennas, separate cabling, separate radio units, separate power supplies, etc. Instead of having a GPS receiver or translator to provide vehicle TSPI and a separate command receiver for the reception of commands from the control point, only one piece of hardware need be provided, with an attendant reduction in antennas, cabling and power supplies. With any of the cases described above, these separate units are combined to save power, space, and weight, all valuable commodities in most unmanned test vehicles. As is seen from the figures, the antenna system, downconverter and wideband amplifier are all shared between the TSPI portion and the telecommand portion of the airborne instrumentation. It is these components which also call for a large share of the electrical power required by any radio receiver, thus an integrated GPS TSPI/Telecommand receiver will require not much more power than a unit used for TSPI only and represents a large savings in battery weight. There can also be a reduction in ground equipment, as well. If there was an existing “pseudosatellite” ground station supporting GPS TSPI, no additional command transmitter would be needed.

CONCLUSION

Since the Test and Training Ranges of the U. S. Government have committed themselves to convert from C-Band tracking radars to GPS as the prime means of obtaining TSPI information, this concept of an integrated GPS TSPI/ Telecommand system offers the advantage of deleting existing separate telecommand systems, both on the ground and as airborne instrumentation, in trade for a slight addition to range instrumentation supporting a GPS-based TSPI system. Such a trade-off means less overall complexity, greater control, greater security, and much less airborne weight, volume and power requirements translating into more payload available on the vehicle. Please note, the GPS modifications proposed herein are the subject of a patent application pending in the US Patent and Trademark Office.