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APPLICATION NOTE 3952

Designing a Low-Cost, Low-Component-Count GPS Receiver

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Abstract: The signals from L1-band global positioning satellites are among the weakest in commercial and private wireless applications. The received power at the antenna of a GPS receiver is buried well below the integrated thermal noise floor. To successfully recover such weak signals, the receiver must have sufficiently high sensitivity, while rejecting out-of-band interferences. The purpose of this article is to describe the key system parameters that should be considered when designing a low-cost, low-component-count, unassisted commercial GPS receiver. This system targets a received sensitivity of -139dBm.

The Global Positioning System (GPS) is an elaborate satellite-based navigational system designed and funded by the United States Department of Defense. The system consists of 24 satellites that continually broadcast their positions and time around the Earth. These satellites travel in one of six orbits, usually with four satellites in each orbit. GPS receivers on earth can receive between five and twelve satellite signals. To acquire a position fix on earth, a minimum of four satellite signals is required—three are used to calculate the latitude, longitude, and altitude of the GPS receiver, while the fourth provides the correct time for synchronization [1].

Click here for an overview of the wireless components used in a typical radio transceiver.

As shown in **Figure 1**, each of the satellites transmits two unique direct-sequence spread-spectrum (DSSS) signals on two carrier frequencies. Spread-spectrum technology is used because it provides a high degree of protection against narrow-band interference. The first carrier frequency resides in the L1 band (centered at 1575.42MHz), while the other resides in the L2 band (centered at 1227.6MHz). The L1 band, intended for civil use, contains two signals. One is called the coarse acquisition (C/A) code and the other is called the precision code (P) code. The L2 band, intended for military use only, carries only the P code. All 24 L1 satellite signals are able to occupy the same frequency without interfering with each other because they are each spread (or coded) by 1 of 32 unique Pseudo-Random Noise (PRN) codes over a bandwidth of 2.046MHz after being upconverted and transmitted.

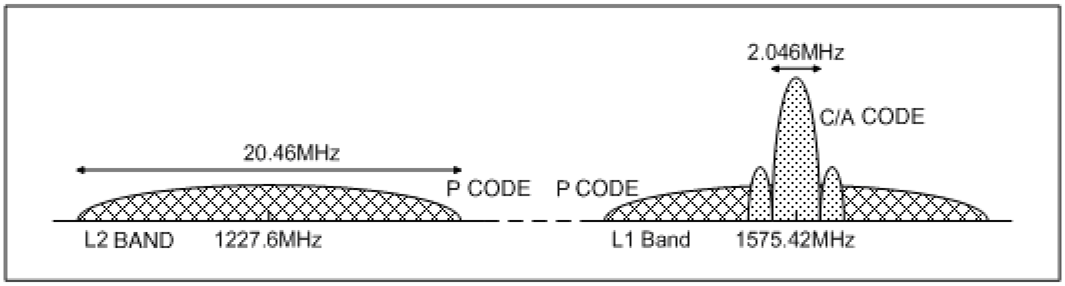

Figure 1. P code and C/A code GPS signals in the L1 and L2 bands.

The spreading of the GPS signal by the PRN code not only distinguishes each signal from the others, but also protects against interference. Immunity against interference is highly dependent on the processing gain of the system. The higher the processing gain, the wider the GPS signal is spread. By spreading the signal over a wide bandwidth, only a fraction of the desired signal can be corrupted by narrow-band interference. After the despreading process, the narrow-band interference is spread. For GPS applications, each PRN code sequence is 1023 bits long, spreading the signal at a rate of 1.023Mbps [2]. Processing gain is defined as:

Processing gain = 10 log (chip rate/data rate) = 43dB (Eq 1)

where chip rate = 1.023Mcps and data rate = 50bps (for our application)

The quality of the despread GPS signal determines the precision of the GPS receiver and is quantified by the resulting bit-error rate (BER). Assuming the baseband processor requires a BER of 10^{-5}, the corresponding post correlator E_b/N_0 for the BPSK modulation used is no less than 9.5dB (AWGN dominated) [3]. E_b/N_0 is defined as the ratio of energy per bit to the spectral noise density. Subtracting 43dB of processing gain from the required 9.5dB post correlator E_b/N_0, the signal-to-noise ratio (SNR) at the correlator input is -33.5dB. Assuming an implementation loss of 3.5dB for software GPS, the SNR required at the quantizer ($SNR_{QUANTIZER}$) input is -30dB. Over a sampled bandwidth of 2.046MHz, the integrated noise power (kTB, T = +290°K) is approximately -111dBm. To achieve a target sensitivity of -139dBm, the required cascaded received noise figure (NF) is the difference between the -28dB SNR at the antenna ($SNR_{ANTENNA}$ = -139dBm/-111dBm) and the -30dB $SNR_{QUANTIZER}$.

$NF = SNR_{ANTENNA} - SNR_{QUANTIZER}$ = -28dB - (-30dB) = 2dB (Eq 2)

As GPS applications become part of an integral solution inside cellular phones and other personal handheld devices, their tolerance of interference caused by neighboring applications within the same unit becomes a key concern. One way of characterizing this tolerance is by measuring the -1dB desensitization point of the receiver. Take a dual-band CDMA cellular phone operating simultaneously with GPS, for example. The typical CDMA transmit power at the power amplifier is +25dBm. Assuming a triplexer and GPS bandpass filter topology for a total isolation of the out-of-band (OOB) signal of 70dB, the GPS receiver would need to be able to withstand an OOB jammer level of -45dBm.

To reduce cost and size, most manufacturers would prefer to use a single common reference frequency when designing multifunction devices. Conventional GPS receivers, however, work only with a 16.36MHz reference frequency; if the GPS receiver is a stand-alone unit, flexible reference inputs are not needed. However, today's handheld devices require various reference frequencies such as 10.0MHz, 13MHz, 14.4MHz, 19.2MHz, 20.0MHz, and 26.0MHz. Therefore, a GPS receiver with a flexible reference input is useful for these devices when lower cost and smaller size are important.

One GPS receiver integrated circuit that meets all three requirements is the MAX2741. This device has an integrated synthesizer, which offers the flexibility in frequency planning by accepting reference frequencies from 2MHz to 26MHz. With an external LNA, the MAX2741 can achieve a cascaded NF of less than 2dB. It also meets the OOB jamming requirement of -45dBm by maintaining a -1dB desensitization level of -37dBm for 800MHz cell phone band and 1800MHz PCS band jammers.

Traditionally, correlation of the received PRN codes to the set of known PRN codes in a GPS receiver is performed by a dedicated GPS baseband processor IC. Thanks to breakthrough software GPS technology, the tasks of correlation and calculation can be replaced by software that resides inside an application processor. Elimination of the dedicated baseband processor not only dramatically reduces the cost, but also drastically reduces the size, of the GPS solution.

The combination of the MAX2741 and software GPS enable the design of a low-cost, low-component-count, unassisted commercial GPS receiver that can achieve -139dBm sensitivity.

A similar article appeared in the February, 2006 issue of *Electronic Products*.

References

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3. R. E. Ziemer and W. H. Tranter. *Principles of Communications*. 4th ed. Wiley, John & Sons, Inc., Dec 1994.

Related Parts		
MAX2741	Integrated L1-Band GPS Receiver	Free Samples

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