A New Tool for CDMA Base Station Site Selection

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Introduction

As Code Division Multiple Access (CDMA) systems grow, both here in the US and all over the world, capacity, interference, and coverage become overriding issues. In order to increase capacity, cells are becoming smaller, with a corresponding proliferation of transmitter/antenna sites. Up until now, CW or narrow band stimulus signals were used to test base station coverage without first putting up an antenna tower and transmitter. More often than not, coverage surveys made with narrow band transmitters are inadequate to measure digital transmission multipath reflections, pseudo noise (PN) pollution, or other parameters unique to a CDMA wireless network. This is because CDMA demodulation depends on the recovery of a PN spreading code, therefore testing requires a standard (IS-95) CDMA signal.

A survey for a digital wireless network must be able to determine interference from multipath reflections of its own signal, as well as interference from other transmitters in the network. In addition, relative power levels must be determined for handoff, cell coverage, and additive PN "noise."

What is needed is a portable CDMA transmitter which allows the user to set transmission frequency channel, RF power level, and base station offset. One such portable transmitter is the BVS Crocodile™ . When used in conjunction with a pilot scanner, the service provider can have a complete picture of coverage and interference of potential base station sites before a large investment in time and money is made.

What is CDMA?

CDMA utilizes spread spectrum technology to achieve high capacity. In addition to conventional frequency channelization, multiple base station cells within each frequency channel (1.25 Mhz wide) are assigned different offsets in time of the PN spreading code. The PN code for IS-95 CDMA phones is 32768 'chip' pseudo random bit sequence. For IS-95, the chip rate is 1.2288 Mhz; the entire code is transmitted in (1/1.2288E6) x (32,768) = 26.66.... ms. This 26.6 ms. rate is referred to as the "frame rate." There are (2/.02666..) 75 frames transmitted every two seconds. To demodulate the signal, the receiver must know the PN code used and correctly correlate it in time with the transmitted PN to retrieve the transmitted information. **Figure 1** demonstrates how the transmitter and receiver PN codes correlate when they are exclusively "NOR'd." By starting the code at different points in time, multiple information channels can occupy the same RF frequency channel simultaneously. In IS-95, the starting points for each PN offset are 64 chips apart, therefore there are (32768/64=) 512 possible base station offsets for each frequency channel. In order for this whole system to work, each base station must have a common and precise reference to universal coordinated time (UTC). This accurate timing reference is made possible by the Global Positioning System (GPS). GPS receivers provide an accurate one second tick, as well as positioning information. In IS-95 CDMA, the PN frames are synchronized to the even UTC second tick from the GPS receiver. **Figure 2** shows the base station offsets in relation to time.

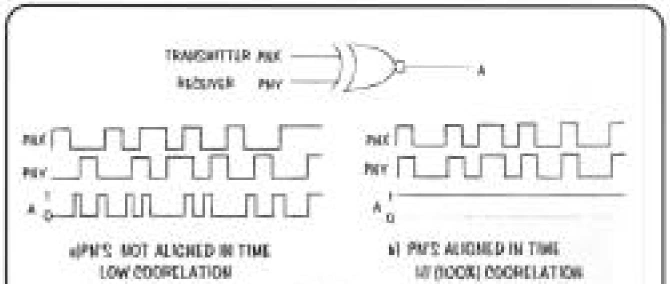

FIGURE 1

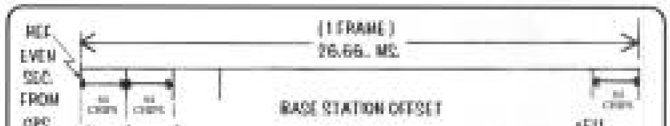

FIGURE 2

The Advantage of CDMA and Some of The Problems

One of the reasons CDMA is desirable is its potential for greater user capacity in a given segment of spectrum. Because calls are differentiated by offsets in time, CDMA offers 8 to 10 times the capacity of an AMPS analog system, and four to five times the capacity of a Time Division Multiple Access (TDMA) system. In order to realize the maximum advantage of CDMA, specialized precision instruments are required. Some of the possible problems that must be checked before putting up a base station are as follows:

Power levels at the fringe areas of the cell for hand-off studies.

Interference from base stations (cells) using the same RF frequency.

Interference from base stations (cells) using the same PN offset.

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Interference from multipath reflections of the original signal, causing both fading of the RF signal as well as corruption of the desired digital information.

It is even possible to be receiving a signal from an adjacent PN offset (i.e. 64 chips away) if it is far enough away (approx. 10 miles) and, therefore, time delayed enough so that the receiver mistakes this signal for the desired base station.

These possible problems can be minimized by selecting the appropriate transmitter site, antenna placement, and PN offset.

Transmitter Requirements

A cost effective tool for CDMA base station site selection must be able to cover the PCS or Cellular forward link frequency bands, allow the user to select the PN base station offset (0-511) and accurately control the transmitted power. The BVS Crocodile™ CDMA transmitter meets these requirements, as well as provides failsafe transmission by constantly monitoring key instrument parameters, thereby preventing unwanted or damaging signals from interfering with an active network. **Figure 3** shows the front panel of the Crocodile™ CDMA transmitter. The Crocodile™ provides the following features:


Figure 3

Frequency range	1.930-1.990 GHz (PCS band) adj. in 30KHz steps (IS-136) 1.930-1.990 GHz (PCS band) adj. in 50KHz steps 0.869.04-0.893.97 GHz (Cellular) adj. in 30KHz steps
Modulation	BPSK, I and Q pilot codes, 1.2288Mhz chip rate
Base station offset	Base station 0 to 511
Clock stability	0.1 PPB (temperature stabilized rubidium clock standard)
GPS receiver	Motorola Encore 8 channel receiver
Failsafe monitor	Checks freq. standard, GPS tick, I and Q modulation, base station offset, CPU watchdog
RF output amp.	10 watt - class A (PCS) 10 watt - class A (Cellular)
Physical	24 lbs. 18" x 15.5" x 7" ruggedized case
Other features	240 X 64 Backlit LCD display, Bell 212a modem with DTMF receiver for remote control
Power requirements	90-250VAC, or 12VDC @ 10 A (PCS), 24VDC @ 8 A (Cellular)

Transmitter Architecture

A block diagram of the Crocodile™ CDMA transmitter is shown in **Figure 4**. The controller is an 80C31 micro-controller that provides user interface and control for the hardware-based PN I&Q generator, as well as the RF frequency generator and power amp control. A rubidium frequency standard provides a highly accurate and stable 10 Mhz reference for both the RF frequency generator as well as the PN generator. A 19.6608 Mhz (16 x chip rate) oscillator is phased locked to this 10 Mhz reference. Once the GPS receiver has locked to at least three (3) of the GPS satellites, the one second pulse is asserted to the PN frame generator, synchronizing it to universal coordinated time (UTC). The GPS one second pulse also synchronizes the 1PPS output of a 7 decade divider, derived from the rubidium standard. This one second pulse is constantly compared to the GPS tick in the failsafe monitor to prevent any frequency drift.

The RF generator/modulator module includes a frequency synthesizer, which allows the user to select an RF channel, and a QPSK modulator for I and Q modulation.

The generator for frames, I and Q PN, as well as the FIR base band filters, are implemented in hardware with five Xilinx 4000 series FPGA's. Two 8 bit DACs convert the band limited digital data to analog I and Q signals for input to the modular. The final amplifier is a class A with

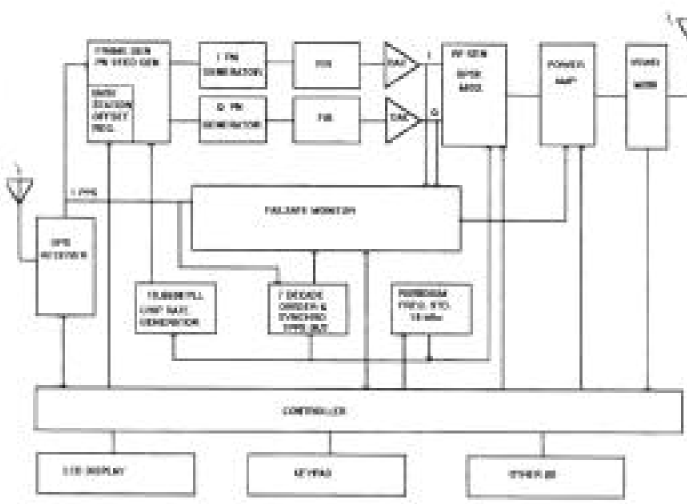
FIGURE 4

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10 watts output that is continuously adjustable in one dB step. The amplifier has an additional 5dB of 'headroom' to handle CDMA peak power (crest factor).

Timing Is Everything

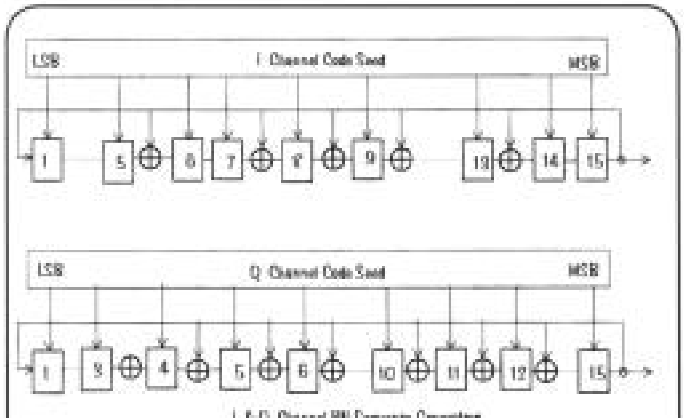
The heart of any spread spectrum transmission system is the PN code. Crocodile™, using a 15 stage feedback shift register, is initialized with a known 'seed' value. The PN is shifted once each chip period (813.8ns). IS-95 requires that the PN sequence start (at the transmitter antenna) is coincident with the UTC's even second time interval. With a 15 stage shift register, the PN code repeats itself every 2^{15} (32768) times, so it may seem like random noise, but, in actuality, it has a known pre-determined sequence. This comes in handy when it is necessary to start the sequence 'early' in order to compensate for delays in the system.

Actually, there are two PN sequences used, one for the 'I' signal, and another for 'Q'. IS-95 describes the PN sequence by the following polynomials:

For I $PI(x) = x^{15} + x^{13} + x^{9} + x^{8} + x^{7} + x^{5} + 1$

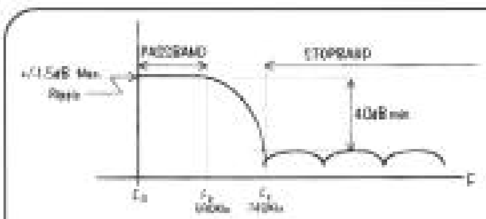
and for Q $PQ(x) = x^{15} + x^{12} + x^{11} + x^{10} + x^{6} + x^{5} + x^{4} + x^{3} + 1$

These generators are implemented as shown in the block diagram of **Figure 5**.



I & Q Channel PN Sequence Generators

Figure 5



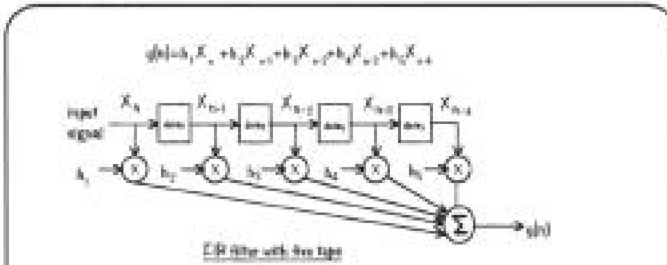
IS-95 Baseband Filter Frequency Response Limits

Figure 6

Baseband Filtering The Digital Way

Since the PN is a high speed digital signal (1.2288 Mega chips per second), considerable filtering is required to maintain the 1.25 Mhz maximum bandwidth as specified in IS-95. The filter essentially strips away all harmonics above the chip rate fundamental frequency (1,2288/2 = 640Khz). IS-95 requires a baseband filter with characteristics as shown in **Figure 6**. Not only would it be impossible to realize such a filter using traditional analog techniques, group delay (phase shifts across the passband) would make it unusable for this application. In the Crocodile™, *finite impulse response* (FIR) digital filters are utilized. Digital filters do not suffer from drift due to temperature, aging, or component tolerance. Because there is no feedback, a FIR is inherently stable, and will not accumulate errors. The FIR filters have a very flat amplitude passband error, sharp cutoff, high rejection in the stopband, are absolutely repeatable, and have no phase error in the passband!

The basic structure of a FIR digital filter is shown in **Figure 7**. The output of the filter at any point in time is a function of the current sample and N-1 previous samples. The output, therefore, is a moving average of a finite number of samples. The bandwidth of the filter, and its rolloff characteristics, are determined by the number of samples N, and the coefficient value $h(n)$ selected for each sample, as well as the precision (bits) of the input data and coefficient values.



FIR filter with five taps

Figure 7

Antenna Site Selection

Many factors must be considered for base station antenna placement. Number of channels, antenna gain, power of the transmitter, beamwidth, height above the terrain, directivity, and interference from existing structures must all be taken into account. By collecting the appropriate data before final site selection, a lot less 'tweaking' will be needed after the installation is completed.

The Crocodile™ CDMA pilot transmitter is intended to be

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used along with a CDMA PN scanning survey receiver, such as the BVS Super Eagle™ PN pilot scanner. The Super Eagle™ allows the user to scan for all possible PN offsets in a selected RF frequency band, and reports to the user all CDMA pilot signal power profiles and S/N ratios; that is, absolute power in dBm and E_c/I_o (energy in correlated PN to total RF channel power in dB) respectively. These measurements are useful in determining CDMA signal propagation, multi-path signals, hand off thresholds and PN re-use.

Typically, the Crocodile™ transmitter is set up in a potential transmitter site and set to the network's RF frequency, as well as the desired Base station offset. A Super Eagle™ is then used to do a geographical survey of CDMA parameters in the cell and surrounding cells. The survey information can be checked in real-time or stored for later analysis. **Figure 8** is a picture of the Super Eagle™ screen showing the Crocodile™ power profile in an existing network.

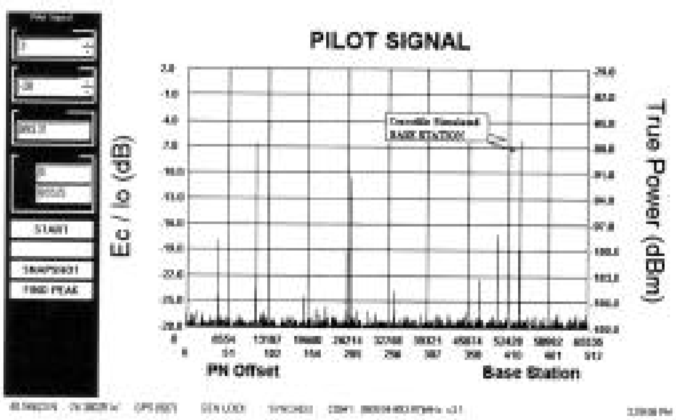

Figure 8

Using A Crocodile

The selected parameter values, system status, and GPS position information are continuously shown on the Crocodile's™ LCD display screen. A change in transmission parameters can only be affected when the RF power amplifier (PA) is turned off. The RF frequency, power out level, and base station offset can be changed via a numeric keypad or rotary dial. In addition, a setup menu allows entry into test and calibration modes.

Because any undesired change in frequency or PN offset can cause havoc to an existing network, the failsafe monitor is constantly checking for proper operation of the system. A loss of any required signal will immediately shut down the transmitter and report the problem to the operator.

Conclusion

Digital wireless networks are expanding at a rapid rate. In order to keep up with the growing demand, network tools must be available to allow service providers to expand network capacity quickly and reliably. The Crocodile™ PN pilot transmitter is one of the next generation of CDMA network tools.

References

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