Real-Time Signal Processing for Cellular, Paging and PCS

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In the first part of this article, the capabilities of digital signal processing (DSP) wireless communications receivers will be described. Such receivers are able to decode, in real-time, all AMPS, ETACS, TDMA (Time Division Multiple Access), and RAMPS (Narrow AMPS) cellular digital control channels, the blank and burst data from all voice channels, and POCSAG, GOLAY, and NEC digital paging traffic, including POCSAG 2400 bit per second transmissions. DSP receivers may also be used as part of a digital signal strength measurement system. After describing the power and applications of DSP receivers in this month's issue, an open interface standard will be described next issue. The standard allows users to build an array of DSP receivers in real-time system monitoring and control without the need for connections to the land line. Customized software or controlling solutions may now be developed around these powerful, yet inexpensive, receivers of the future.

Introduction
With the rapid emergence of a wide variety of wireless communications standards throughout the world, there is an increased demand for wireless digital signal processing (DSP) receivers that can measure cellular, paging, and Personal Communications Networks (PCN) radio system performance in real-time.

By using a distributed array of DSP receivers, where each receiver is capable of receiving traffic from a local geographic area, it becomes possible to adaptively control and monitor frequency allocations and transmitter power levels for optimum capacity in real-time, without any type of connection to telephone switches or terminals. Furthermore, with a distributed data collection system, interference levels and traffic or calling patterns may be monitored and analyzed instantly and easily from specific locations or at a master control point. Such a system provides instant information on calling patterns, user demand, rapid fraud detection, and antenna pointing capabilities in any wireless system. When combined with global positioning system receivers (GPS), these DSP receivers can offer a wide range of wireless system monitoring and...
coverage measurement capabilities.

In this article, we demonstrate how such receivers may be used to control emerging wireless system components such as adaptive base station antennas, interference sensors and channel allocation hardware for personal communication systems, Intelligent Vehicle Highway Systems (IVIS), and RF waveform capture. While DSP receivers are likely to become the norm as wireless systems proliferate throughout the globe, there are currently very few that are commercially available for all-purpose wireless reception. Some of them are the CELSCOPE, PAGETRACKER, and POWERTRACKER family of DSP receivers (see Figure 1).

In expanding cellular radio markets, it is becoming necessary to measure traffic activity so that systems can be adjusted to provide coverage where subscribers are most likely to require service. In urban cellular markets, changing traffic patterns, volatile shifts in user demands, and migration from mobile to hand-held portable cellular phones require that near real-time control of the cellular telephone system be provided in order to exploit potential local increases in demand with fixed resources. Also, wireless system providers require flexible, portable measurement systems that allow engineers to rapidly determine cellular or paging coverage needs, system faults, areas of traffic congestion, and customer usage profiles. Fraud is also a concern to cellular carriers and is becoming a major problem in the cellular radio community. In the United States alone, the Cellular Telecommunications Industries Association (CTIA) estimates that over $1 million in revenue is lost to fraudulent cellular users every day [1].

The ability to rapidly scan banks of radio spectrum is becoming important for cellular and personal communication systems which employ new dynamic channel allocation algorithms, and for personal communication systems which will share spectrum with fixed microwave users. By scanning the spectrum, a mobile telephone switching office can instantly determine the interference profiles and available channels throughout a system. An inexpensive measurement system with flexible bandwidths and rapid scan rates can be used within a real-time dynamic allocation strategy for wireless services in shared-spectrum applications.

DSP receivers are also well-suited for use in digital paging and cellular terminals and cell sites as an independent means of confirming "on-the-air" traffic. The CELSCOPE and PAGETRACKER receivers by TSR Technologies integrate a Global Positioning System to allow position location data to be recorded with all traffic. The system monitors allow instant viewing of all measured data and position information, and users may visualize, process, and filter all recorded data in just a matter of seconds, using post-processing programs that operate on the collection of real-time data.

TSR Technologies Inc. developed the CELSCOPE and PAGETRACKER DSP receiving systems especially for cellular and paging service providers throughout the world. More recently, the POWERTRACKER receiver was developed for system integrators and PCN providers. The goal in each system is to provide powerful data recording features in an easy-to-use system monitor. For example, while an RF engineer may be interested in one particular aspect of CELSCOPE, there are other functions which are of extreme importance to a marketing director. Still another set of features is indispensable to drive testing engineers who are responsible for plotting coverage. Yet another function can be used for engineers who are responsible for writing the low level code for MTSO switching.

**CELLSCOPE**

CELLSCOPE is able to decode every bit of real-time traffic on any AMPS or ETACS cellular system, and is able to decode all digital TDMA and NAMPS control channels as well. This receiving system can monitor and store, in real-time, the calling records of up to 150,000 users at once, and when used within a car or van, can follow calls throughout a cellular system as they are handed off. Also, this receiving system keeps track of the exact number and time of occurrence of pages, analog channel assignment, digital channel assignments, recorders, retries, and other important data, in absolute real time and with no connection to the MTSO. By monitoring the off-air signal, CELSCOPE can be moved to potential base station locations, or microcell locations, in order to test the reception and amount of traffic of a prospective site. It also provides a printing capability and system trigger signals that can be used for alarms or counting devices whenever signal levels drop below certain thresholds, whenever certain subscriber numbers are activated, or whenever certain telephone numbers are dialed. All control channel (set-up channel) data are received in real-time, and can be stored either in ASCII or hexadecimal format.

The user interface for the CELSCOPE 2000 is shown in Figure 2, and offers real-time information about all aspects of the cellular system with a simple glance of the screen. Hot keys on any PC allow the receiving system to quickly configure for different operating modes. An on-line help menu obviates the need for a manual, as instructions and helpful hints are provided with a simple press of the F1 key.

This system has been used for drive testing, market research, monitoring of the reverse control channel to determine MTSO performance, and many other applications. The power of DSP can be seen by considering a novel use of the CELSCOPE by some stateside
carriers. DSP can be used to take an electronic snapshot of any RF wave- 
form. By capturing the waveforms of every subscriber telephone, it becomes possible to provide "RF fingerprinting" of each customer's phone. The idea of RF fingerprinting allows each sub- 
scriber unit to be identified by unique characteristics of its radio signal, pro- 
duced by the specific components within the subscriber phone. DSP con- 
verts this radio signal snapshot into a specific characterization, which can be stored in a database and compared to future calls made by the same MIN and ESN. CELLSCOPE's ability to read every MIN and ESN signal generated by a pool of subscribers, and its ability to 
activate an external trigger signal, makes it a low cost front end compo- 
nent for emerging RF fingerprinting systems which must first testize every subscriber signal, and then access the database of stored fingerprints to de- 
termines if there is a report of trouble or a missed page. In fact, its ability to measure above 1 GHz makes it an ideal off-the-shelf product for testing new cellular and PCS sys- 
tems that are being deployed throughout the world. Figure 3 illustrates the 
PAGETRACKER user interface. Like CELLSCOPE, on-line help and an easy- 
to-use hot key system allow different modes and options to be sent quickly 
and easily.

PAGETRACKER can simultaneously decode all of the digital paging stan- 
dards in use today, and supports automated or customized spectrum scan- 
ing. Scans are guaranteed at a rate of 10 frequencies per second, with seven samples per frequency, although it is possible to achieve 20 frequencies per second using a personal computer with a 25 MHz clock speed. In addition, the 
real-time paging statistics of any paging transmitter can be recorded and stored in real-time for analysis of customer traffic patterns, popularity of stan- 
dards, popularity of alpha or numeric paging, and transmitter on-time. Also, 
the system provides printouts and activ- 
ates external trigger signals on thousands of specific cap-codes, paging 
messages, or message lengths.

The PAGETRACKER scanning fea- 
ture, when used with the NAVTRACKER global positioning system receiver, 
makes it possible to integrate GPS posi- 
tioning data with as many as 1,024 specific frequencies. The resulting database is 
in easy-to-read ASCII for mapping or 
post processing. For applications in 
previously uncharted radio environ- 
ments, or for measuring environments 
that change rapidly, PAGETRACKER has an automated scan feature that al- 

ers remote, automated scanning of 
any spectrum. After letting the receiv- 
ing system run for a few hours or a few 
days, it is possible to determine the 

each spectrum occupancy of a particu- 
lar market over the 25 MHz to 2000 

MHz range. Such scanning features are in demand for federal licensing agen- 
cies which rely on measurements of the spectrum, or require license appli- 
cants to demonstrate proof of spec- 

trum usage.

PAGETRACKER's ability to simulta- 

eously measure real-time paging traf- 
ic with signal strength for all digital standards makes it a powerful system 

for validating all paging traffic, with time and date stamp, sent on any pag- 
ing channel. One of the largest vacation 

terms in personal wireless communica- 
tions.

The low level serial interface stan- 
dard for the POWERTRACKER has been 
expanded upon, and now each of the 
CELLSCOPE, PAGETRACKER, and PO- 
WERTRACKER receivers be controlled by 

custom applications. The TSR Interface 
standard allows customers to cus- 

tomize the receivers for a myriad of 
applications. For example, a large number of receivers may be controlled by a sin- 
gle workstation by using the described 

standard and some simple off-the-shelf hardware. Using the standardized con-
If a cellular data transmission does not pass the majority vote test, the receiver does not pass the corrupted data to the serial interface. The receiver and controller are responsible for receiving and buffering all serial interface data from the DSP receiver. Thus the host must be configured in such a way that when serial data is received, it immediately reads that data. Since standard personal computers have universal asynchronous receiver-transmitters (UARTs) connected to their serial ports (COM ports), this is a simple task, and is readily accomplished by controlling software. The host's UART receives the serial data and converts it to parallel data for controlling purposes. Once each serial data byte is received, the UART sets the new data available bit in its status register. The UART's status register also has the overlow bit which indicates if the last unread data in the UART was overwritten by new data. The controller can use the status register and data register of the COM port to send and collect data from the CELLSCOPE/PAGETRACKER/POWERTRACKER unit.

Applications and Conclusion

The DSP receivers described above have an easy-to-use computer interface, and are currently in use throughout the world as flexible, all-in-one cellular, paging, and PCS system measurement tools. There are numerous applications for DSP receivers, including distributed processing, remote terminal applications, system measurements, and fraud abatement, that the above open interface standard could support. Multiple DSP receivers can be connected together at a common base, using landline, microwave radio, or existing T1 channels to support real time RS-232 data transmission. A distributed network of DSP receivers described in this paper, each with their own local controllers, could provide real time traffic monitoring, system control and intelligent network support in a wide range of wireless systems.

In part two of this article (coming in the next issue of Global Communications) the open digital interface standard for the CELLSCOPE/PAGETRACKER/POWERTRACKER family of receivers will be described in detail.

With an open interface, users may use these DSP receivers for a multitude of applications.

About the Authors

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