EDN DESIGN FEATURE

Special-purpose signal sources invade wireless-communications R&D

DAN STRASSBERG, SENIOR TECHNICAL EDITOR

Although general-purpose RF-signal generators retain a place in wireless-communication product design, instruments tailored to individual standards are growing in importance. Special-purpose generators now fit more than just manufacturing and field use.

Designers of digital wireless-communication products regularly face more than a few of electronics' toughest challenges. These intrepid EEs must continually squeeze more bytes per second into narrower slices of the RF spectrum. In addition, wireless products often must simultaneously satisfy conflicting constraints on power consumption, cost, weight, size, and signal integrity in the presence of channel impairments. What's more, even the most sanguine engineer is likely to experience vertigo when confronting the dizzying array of specifications that standard-setting bodies use to prescribe system performance and test methods.

When the time comes to validate a new design in the R&D lab, selecting the right combination of test equipment is no easier than the rest of wireless-product design. Although you can make some measurements with groups of general-purpose instruments, standardized data-interchange and test protocols often force you to use specialized units.

Most setups built from general-purpose devices can't perform basic tasks that special-purpose units handle with ease. Initiating a call to a prototype mobile station is an example. Attempting to circumvent the instrumentation problem by routing test calls through an operating base station doesn't work; you can't control the signal parameters well enough to perform the desired tests. In fact, characterizing the signals that the base station transmits becomes a whole new measurement problem.

Still, despite their advantages, special-purpose test sets often prove less than ideal in R&D. In many cases, the units' designers had in mind manufacturing and field uses. In these applications, the flexibility and accuracy that R&D engineers need take a back seat to ease of use and measurement speed. As a result, until recently, most design engineers have had to work with both general-purpose and protocol-specific instruments. Some still must do so.

Interfaces that use large alphanumeric (and sometimes graphical) flat-panel displays are the norm in wireless-communication signal sources. Rohde and Schwarz's SMIQ series (available from Tektronix in the United States and Canada) covers 200 kHz to 3.3 GHz and offers optional multipath-fading simulation.

Still more specialization

For certain tests, even a combination of general-purpose and protocol-specific test equipment doesn't suffice. R&D engineers' setups sometimes require still-more-specialized instruments and systems. Signal-impairment and fading simulators are examples (see **box** "Fading—an acid test of wireless-system robustness"). Moreover, communications devices, such as mobile phones, that nominally support the same protocol often incorporate vendor-specific features. Testing those features can require customized test equipment. Although field-repair depots comprise the primary market for brand-specific telephone test sets, R&D uses of such testers do exist.

On the one hand, the growing specialization of so much wireless-communications test equipment exacerbates R&D labs' need for multiple instrument classes. On the other hand, the appearance of new classes of multifunction testers should at least slow the growth of

@a glance

- Choosing test equipment for characterizing wireless-communication products in R&D is no simple task.
- General-purpose instruments offer flexibility and accuracy, but only a few support testing in accordance with the specialized standards that govern the products under test.
- One-box test sets provide support for the specialized standards but, traditionally, have sacrificed flexibility and accuracy to achieve ease of use and short test times.
- A new generation of flexible, high-accuracy, protocol-specific signal generators is emerging to satisfy R&D engineers' needs.
- Even with these signal sources, R&D engineers often need even more highly specialized test-equipment.

that need. Among the new classes are the RF signal sources that several companies have started to offer. These instruments provide the accuracy and flexibility of general-purpose units and the specialized features of protocol-specific, "one-box" testers. A few instruments of this sort even simulate transmission impairments, although not as comprehensively as do more expensive signal-impairment simulators.

Fortunately, no instrument needs to support all the wireless-communications systems because no R&D department deals with more than a few of the systems. (**Table 1** provides key parameters of more than 20 systems.) Instruments usually support one standard or a small group of closely related ones.

Engineering managers often worry about the longevity of their test-equipment purchases. These managers want assurance that this year's test-equipment expenditures won't go to waste if next year's project involves a different standard. Modular architectures allow many protocol-specific units to meet this demand. Manufacturers can replace modules in instruments already in customers' hands and thus enable the units to support different protocols. Reconfigurability is more of a security blanket for purchasers than a useful feature, though. The likelihood of actually reconfiguring an instrument to support a different standard is low.

Benefits for manufacturers

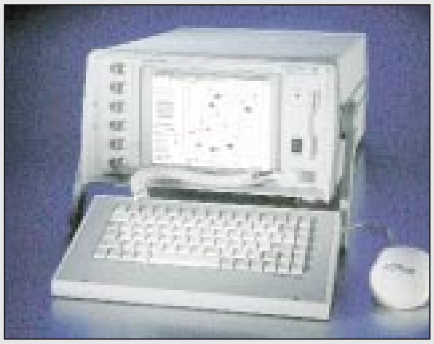
For instrument manufacturers, reconfigurability is simply a fallout of efficient design. Digital wireless-communication standards have enough elements in common that real eco-

(continued on pg 108)

FADING—AN ACID TEST OF WIRELESS-SYSTEM ROBUSTNESS

Unlike old soldiers, digital wireless signals *do* die, or "drop out," when they fade away. And although the signals sometimes rise from the dead, resynchronizing the receiver with the transmitter after a dropout often takes an appreciable time. During that time, data is lost, making dropouts at best undesirable, and often unacceptable.

Immunity from the effects of signal impairments is hardly the only measure of a system's robustness. But fading characteristics are important, especially for mobile and handheld devices. For Elektrobit, Noise/Com, and Telecom Analysis Systems, a major line of business is supplying test equipment that design engineers use to characterize their systems' fading performance. Rohde and Schwarz also offers some fading-simulation capabilities in its SMIQ signal generators. With this option, engineers can perform certain fading tests while avoiding the cost of a full-fledged fading simulator. (Full-featured fading simulators can cost more than $50,000. Most R&D labs own no more than one or two such units.)



Fading emulators allow testing for the effects of signal impairments under controlled laboratory conditions. This unit, the MP2700, comes from Noise/Com.

Most digital wireless-communication systems operate at 800 MHz to 2 GHz. Reception can be tricky at these frequencies, especially in cities, where buildings reflect signals and shield receiving antennas. Another problem area is in fast-moving vehicles, where transmission-path characteristics change rapidly. It should surprise no one that wireless communication is nowhere more popular than in moving vehicles in cities.

Radio propagation is a subject of much study and analysis. Researchers have characterized and named several types of fading. The types that most concern developers of wireless systems are Rayleigh, Rice, and log-normal.

Rayleigh, or short-term, and Rice, or Rician, fading are consequences of multipath reception, in which signals reflect from different objects and arrive at the receiving antenna at slightly different times. In Rayleigh fading, the direct, unreflected path is obstructed, and all arriving signals are reflections. A Rayleigh probability-density function describes the distribution of arriving-signal amplitudes. In Rician fading, there are both reflections and a line-of-sight path to the transmitting antenna. Because of the line-of-sight path, the amplitude varies less than in Rayleigh fading.

When the receiving antenna is moving, two other multipath effects come into play. Both effects broaden the received signal's spectrum. Typically, multiple reflected signals arrive from different angles, resulting in multiple Doppler frequency shifts. Each Doppler shift depends on the moving antenna's velocity and the angle between the direction of motion and the path from the reflecting object to the antenna. The result is an effect called Doppler spread.

Doppler spread is a frequency-domain characterization of multipath effects on a signal that a moving antenna receives. Delay spread is a time-domain characterization of the same phenomenon. In the time domain, the effects are easier to understand; they can cause intersymbol interference. The signals representing data from multiple symbol periods can simultaneously arrive at the antenna. The result is unpredictable outputs from the receiver's demodulator.

DIGITAL MODULATION—A MATTER OF I-Q

I-Q or vector modulation does not directly relate to intelligence quotients; I-Q refers to in-phase and quadrature. Nevertheless, many engineers think that developing the I-Q-modulation concept and technology involved a stroke of genius.

Vector modulation (of which quadrature-amplitude modulation, or QAM, is a popular type) is at the heart of most digital wireless-communication systems. QAM packs multiple data bits into single symbols, each of which modulates the carrier's amplitude and phase. Phase is measured with respect to that of an unmodulated carrier. In systems currently in production, one symbol can represent as many as 2^{10} (1024) values, or 10 bits, but systems that pack smaller numbers of values (usually 16 or 64, equivalent to 4 or 6 bits) into one symbol are more common.

The easiest way to visualize vector modulation is in the I-Q plane (Figure A). The length of a vector drawn from the origin represents the carrier amplitude during transmission of each symbol. The angle between the vector and the horizontal (I) axis represents the phase of the carrier when the symbol is transmitted. The time allowed for transmitting one symbol is called the symbol time, or symbol period. The data rate in bits per second is N times the symbol rate, where the symbol rate is the reciprocal of the symbol time and N is the number of bits per symbol.

Thinking of signals in the I-Q plane

Although you can think of amplitude and phase as independent quantities, it is both conceptually and practically easier to deal with the I and Q components (the projections of the vector onto the I and Q axes). In 16-level QAM (16QAM), I and Q can each have four possible values or states. Representing four states requires 2 bits. So when you pack 4 bits into one 16QAM symbol, the I component might represent the 2 most significant bits and the Q component might represent the 2 least significant bits.

If, at the end of a symbol period, the signal could jump in zero time from one pair of I and Q values to a different pair, the signal would be discontinuous and would occupy infinite bandwidth. Clearly, a system that allowed such discontinuities would make inefficient use of bandwidth and, indeed, would defeat the purpose of packing many bits into one symbol.

So the I-Q-modulated signal must be filtered to limit its bandwidth. Generally, you accomplish this filtering by developing baseband I and Q signals and passing them through lowpass filters.

Viewed as functions of time, the I and Q signals are a pair of multivalued analog waveforms. In 16QAM, each of the waveforms has four possible values, corresponding to the states 0/0, 0/1, 1/1, and 1/0 of the bit pair that the signal represents. Before filtering, the waveforms have vertical rising and falling edges and perfectly square corners. After filtering, the rising and falling edges are more gradual, the corners are more rounded, and, depending on the filter characteristics, overshoot or ringing may exist at the corners.

Raised-cosine filters

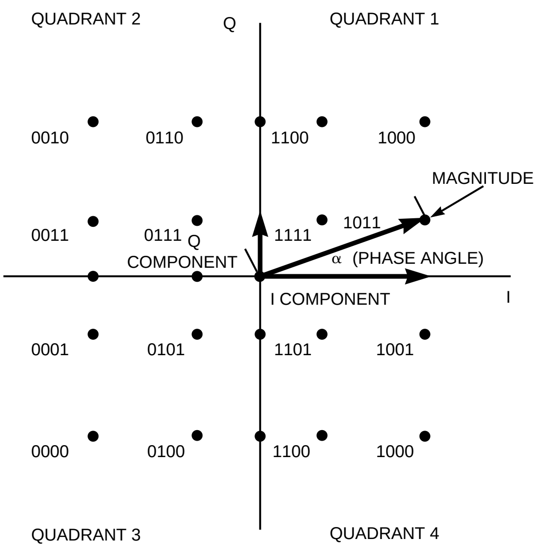
To limit the signal bandwidth, many vector-modulation systems use so-called raised-cosine filters. These filters' characteristics are flat in both the passband and the stopband. The transfer ratio is 1 in the passband and 0 in the stopband. On a linear frequency scale, the characteristics in the transition band resemble 180° of a 0.5-amplitude cosine function raised by (added to) a fixed value of 0.5.

The amplitude response passes through 0.5 (that is, –6 dB) at the cutoff frequency, which is usually $\sqrt{2}$ times the symbol rate. (Remember that the fundamental-frequency component of the baseband I and Q signals is at one-half the symbol rate.) The parameter r measures the sharpness of the filter cutoff. An r of zero indicates that the transition band has zero width in the frequency domain (a so-called brick-wall filter). Practical filters have r values as low as 0.11, but typical values are usually above 0.3. The maximum value of r is 1. With this value, the amplitude response begins rolling off gradually at dc and reaches zero at twice the cutoff frequency.

The bandlimited waveforms go to the inputs of an I-Q modulator. The I signal then modulates a carrier whose phase has not been shifted. The Q signal modulates an equal-amplitude carrier whose phase has been shifted within the modulator by 90° ($\pi/4$ radians) with respect to the first carrier. Each modulation operation can affect the associated carrier's amplitude and either reverse or leave unchanged the carrier's phase. Vectorially adding the two modulated carriers produces an I-Q-modulated carrier.

You can use a stand-alone, two-channel arbitrary-waveform generator (ARB) to generate baseband I and Q signals. In fact, Tektronix offers a PC-based software package, IQSim, which synthesizes data streams that you can send to a two-channel ARB to produce the baseband signals. You can apply these signals to the modulation inputs of an RF-signal generator that includes an I-Q modulator. You should be sure, however, that the ARB is properly specified for this application. The ARB's two channels must operate from a common clock. The ARB must also include lowpass output filters whose characteristics closely match each other and are properly specified for producing I and Q inputs for a modulator.

FIGURE A



EFFECTS OF MODULATION ON CARRIER PHASE

QUADRANT	I PHASE	Q PHASE
1	UNCHANGED	UNCHANGED
2	REVERSED	UNCHANGED
3	REVERSED	REVERSED
4	UNCHANGED	REVERSED

In this 16-level QAM constellation, one symbol represents 4 bits. Two bits modulate the carrier's in-phase component (I), and 2 bits modulate the quadrature component (Q). In the output (the vector at about 30° to the I axis), the data resides in the carrier's amplitude and phase.

nomic benefits result from using interchangeable modules to create instrument families that support multiple standards (see **box** "Digital modulation—a matter of I-Q").

Rohde and Schwarz's SMIQ RF vector signal generators, and Hewlett-Packard's ESG-D series of digital RF-signal generators exemplify the new breed of multifunction wireless-signal sources. SMIQ unit prices begin at $16,000. Tektronix is the exclusive source for Rohde and Schwarz products in the United States and Canada. HP's ESG prices range from $14,000 to $19,000.

Some protocol-specific test sets perform even more functions than these signal sources do. For example, HP's $60,000 8922 GSM mobile-station test set incorporates computation and analysis capabilities that are not normally part of signal sources. The unit performs functional tests as well as parametric measurements of the type that R&D engineers make in characterizing new product designs. Even so, the 8922 fits in one box.

With the continuing growth in wireless technology, you can look for acceleration of the trend toward instrumentation that is at once highly specialized and broad in capability. Such products will perform an extensive array of functional tests and parametric measurements, but only in accordance with narrowly defined standards. Because of its strong influence on users' selection of suppliers, ease of use will be a key issue in the design of these instruments. EDN

More and more wireless-communication test gear is specific to particular standards. Marconi's 2052T supports the TransEuropean Trunked Radio (Tetra) standard. The generator produces less than –70-dBc adjacent-channel power.

References

1. Hewlett-Packard Co, *Digital modulation in communications systems—an introduction*, Application Note 1298, P/N 5965-7160E, Palo Alto, CA, July 1997.
2. Tektronix Inc, *Signals and measurements for wireless-communications testing*, Beaverton, OR, April 1997.
3. Owen, David, *Fading and multipath*, Marconi Instruments, Publication no. 469889-473, Fort Worth, TX, January 1994.
4. Owen, David, *An introduction to digital and vector modulation*, Marconi Instruments, Publication no. 46889-476.

You can reach Senior Technical Editor Dan Strassberg at 1-617-558-4205, fax 1-617-928-4205, e-mail ednstrassberg@cahners.com.

(Turn to pg 110 for Table 1)

VOTE

Please use the Information Retrieval Service card to rate this article (circle one):

High Interest	Medium Interest	Low Interest
594	595	596

FOR MORE INFORMATION...

For more information on products such as those discussed in this article, circle the appropriate numbers on the Information Retrieval Service card or use *EDN*'s Express Request service. When you contact any of the following manufacturers directly, please let them know you read about their products in *EDN*.

Advantest
In North America,
see Tektronix

Anritsu Co
Richardson, TX
1-972-644-5353
fax 1-972-644-5494
www.anritsuwiltron.com
Circle No. 314

Elektrobit Ltd
Oulu, Finland
+358-424-9999-1
fax +358-424-9999-329
www.elektrobit.fi
Circle No. 315

Giga-tronics
San Ramon, CA
1-800-726-4442
1-510-328-4650
fax 1-510-328-4700
Circle No. 316

Hewlett-Packard Co,
Test and Measurement Organization
Palo Alto, CA
1-800-452-4844
www.hp.com/go/tmdir
Circle No. 317

IFR Systems Inc
Wichita, KS
1-800-835-2352
1-316-522-4981
fax 1-316-522-1360
www.ifrsys.com
Circle No. 318

Marconi Instruments
Fort Worth, TX
1-800-233-2955
1-817-224-9200
fax 1-817-224-9201
www.Marconi-Instruments.com
Circle No. 319

Noise/Com
Paramus, NJ
1-201-261-8797
fax 1-201-261-8339
www.noisecom.com
Circle No. 320

Racal Instruments
Irvine, CA
1-714-859-8999
fax 1-714-859-7139
www.racalinst.com
Circle No. 321

Rohde and Schwarz
In the United States
and Canada,
see Tektronix

Telecom Analysis
Systems Inc
Eatontown, NJ
1-732-544-8700
fax 1-732-544-8347
www.taskit.com
Circle No. 322

Tektronix Inc
Beaverton, OR
1-800-426-2200
1-503-627-1916
fax 1-413-448-8003
www.tek.com
Circle No. 323

Wavetek Corp,
Wireless Communications Division
Indianapolis, IN
1-317-788-9351
fax 1-317-788-5999
www.wavetek.com
Circle No. 324

Super Circle Number

For more information on the products available from all of the vendors listed in this box, circle one number on the reader service card.

Circle No. 325

TABLE 1—KEY CHARACTERISTICS OF DIGITAL WIRELESS-COMMUNICATIONS SYSTEMS

System name	APCO-25	CDPD	CDMA	CT-2	CT-3	DECT	D-MCA	ERMES	GSM/PCN/ DCS-1800
Geography	North America	North America	North America	United Kingdom	Europe	Europe	Japan	Europe	Europe
Year of introduction	NA	NA	1992 to 1993	1989	1990	1992 to 1993	NA	1993	1991
Estimated no. of users by 2000	NA	NA	NA	NA	NA	NA	NA	NA	GSM: 15 million to 20 million; DCS-1800: 4 million to 13 million
Type of service	Public safety	NA	Public cellular	Cordless telephony	Cordless telephony	Wireless private-branch exchange	NA	NA	Public cellular
Frequency range	Less than 1 GHz	824 to 849 MHz, 869 to 894 MHz	824 to 849 MHz, 869 to 894 MHz, 1850 to 1990 MHz	864 to 868 MHz	800 to 1000 MHz, 1800 MHZ in future	1.88 to 1.9 GHz	850 to 860 MHz, 905 to 915 MHz, 1501 to 1525 MHz, 1453 to 1477	169.4 to 169.8 MHz MHz	935 to 960 MHz, 890 to 915 MHz, 1.7 to 1.9 GHz
Data structure	FDMA	FDMA	CDMA	TDD	TDMA	TDMA/ TDD	TDMA	NA	TDMA
Modulation	š/4 DQPSK or four-level FM	0.5 GMSK	Base station: QPSK; mobile station: OQPSK	Two-level GFSK ± (14.4 to 25.2) kHz	GMSK 160 kHz	GFSK ± (259 to 317)-kHz deviation	M16QAM	FFSK	0.3 GMSK
Mobile output power	NA	NA	0.2 mW to 6.3W	1 to 10 mW	NA	250 mW	NA	NA	20 mW to 20W
Modulation data rate	9.6 kbps	19.2 kbps	1.2288 Mbps (spreading)	72 kbps	640 kbps	1.152 Mbps	64 kbps	6.25 kbps	270.833 kbps
Bit duration	NA	NA	813.8 nsec	13.8 msec	NA	868 nsec	NA	NA	3.692 msec
Filter	Root Nyquist (square root raised cosine)	0.5 Gaussian	FIR	0.5 Gaussian	0.5 Gaussian	0.5 Gaussian	0.2 root Nyquist (square root raised cosine)	10th-order Bessel 3.9 kHz	0.3 Gaussian
Channel bandwidth	12.5 kHz	30 kHz	1.25 MHz	100 kHz	100 kHz	1.728 MHz	25 kHz	12.5 kHz	200 kHz
No. of carriers	NA	NA	2×20	40	Eight	10	NA	NA	124
Channels per frequency	NA	One	55 (plus nine dedicated)	One up, one down	NA	12	Three	NA	Eight or 16
Frame length	NA	NA	NA	NA	NA	10 msec	NA	NA	4.615 msec
Time-slot length	NA	NA	NA	NA	NA	0.417 msec	NA	NA	0.577 msec
Burst length	NA	NA	NA	NA	NA	424 bits	NA	NA	147 bits
Speech codec	IMBE 4.4 kbps	9.6 kbps	Variable rate 9.6 to 1.2 kbps, 14.4 to 3.6 kpbs	ADPCM 32 kbps	NA	ADPCM 32 kbps	Less than 7.467 kbps	NA	RELP-LTP 13 kbps
Specification	EIA TSB 102.CAAA	CDPD Spec 1.0 July 19, 1993	EIA/TIA IS-95 (B)	MPT 1375 Common Air Interface	NA	Customer Interface Spec Part 1	JTC	NA	GSM Standard

Note: Table is based on material furnished by Anritsu Co, Hewlett-Packard Co, and Tektronix Inc.

iDEN (MIRS)	JDC/PDC	JDCT/ PHP/ PHS	Mobitex	Modacom	NADC/ D-AMPS/ IS-136	PACS	PCS-1900	PWT (WCPE)	Tetra	TFTS
North America	Japan	Japan	United States, Canada, Scandinavia	Europe, United States	North America	North America	North America	North America	Europe	Europe
1995	1991 to 1993	1991 to 1992	1991	NA	D-AMPS 1991, IS-136 1992	NA	NA	NA	NA	NA
NA	5 million	PHS: 6.5 million to 13 million	NA	NA	35 million to 40 million	NA	NA	NA	NA	NA
Dispatch, cellular telephony, conference calling	Public cellular	Cordless telephony, personal communications	NA	NA	Public cellular	NA	NA	NA	NA	NA
850 to 860 MHz, 905 to 915 MHz, 1501 to 1525 MHz, 1453 to 1477 MHz	810 to 826 MHz, 940 to 956 MHz, 1429 to 1441 MHz, 1447 to 1489 MHz, 1453 to 1465 MHz, 1501 to 1513 MHz	1895 to 1918 MHz	Subject to change	410 to 430 MHz	824 to 849 MHz, 869 to 894 MHz 1850 to 1990 MHz	1850 to 1990 MHz	1850 to 1990 MHz	1910 to 1930 MHz (unlicensed)	450 MHz, less than 1 GHz	1593 to 1594 MHz, 1625 to 1626 MHz
TDMA	TDMA	TDMA	NA	NA	TDMA	TDMA	TDMA	TDMA/ TDD	TDMA	NA
M16QAM	š/4 DQPSK	š/4 DQPSK	GMSK with FFSK subcarrier	FFSK	š/4 DQPSK	š/4 DQPSK	0.3 GMSK	š/4 DQPSK	š/4 DQPSK	š/4 DQPSK
NA	To 2W	80 mW	NA	NA	2.2 mW to 6W	NA	NA	NA	NA	NA
64 kbps	42 kbps	384 kbps	8 kbps; 1.2 kbps subcarrier	9.6 kbps	48.6 kbps	384 kbps	270.833 kbps	1.152 Mbps	36 kbps	44.2 kbps
NA	23.8 msec	NA	NA	NA	20.6 msec	NA	NA	NA	NA	NA
0.2 root Nyquist (square root raised cosine)	0.5 root Nyquist (square root raised cosine)	0.5 root Nyquist (square root raised cosine)	0.3 Gaussian	Cosine r = 0.2	0.35 root Nyquist (square root raised cosine)	0.5 root Nyquist (square root raised cosine)	0.3 Gaussian	Root Nyquist	0.35 root Nyquist (square root raised cosine)	Cosine r = 0.4
25 kHz	25 kHz	300 kHz	12.5 kHz (United States) 25 KHz (Japan)	12.5 kHz	30 kHz	300 kHz	200 kHz	NA	25 kHz	25 kHz
NA	1600	39	NA	NA	832	NA	NA	NA	NA	NA
Six	Three or six	Four or eight	NA	NA	Three or six	Eight	Eight or 16	12	One to 150	NA
NA	20 msec	NA	NA	NA	20 msec	NA	NA	NA	56.67 msec	NA
NA	6.66 msec	NA	NA	NA	6.66 msec	NA	NA	NA	14.167 msec	NA
NA	280 bits	NA	NA	NA	324 bits	324 bits	NA	NA	NA	NA
Less than 7.467 kbps	VSELP 8 kbps	ADPCM 32 kbps	NA	NA	VSELP, ACELP, 8 kbps	ADPCM 32 kbps	RELP-LTP 13 kbps	ADPCM 32 kbps	7.2 kbps	NA
Customer Interface Spec Part 1	RCR – 27F	RCR-28	NA	NA	D-AMPS: IS-54B, 55, 56; IS-136A: EIA/TIA IS-136, 137, 138	JTC PN3418	TIA/JTC Standard	Customer Interface Spec Part 1	ETS 300 ETS 394-1	NA

(Turn to pg 112 for glossary)

GLOSSARY OF DIGITAL WIRELESS-COMMUNICATIONS SYSTEMS

ACELP: Adaptive code-excited linear prediction
ADPCM: Adaptive digital pulse-code modulation
AMPS: Advanced Mobile Cellular-Phone Service
APCO: Association of Public Safety Communication Officials
CAAA: Channel-Aggregation Access Arrangement
CT: Cordless telephone
D-AMPS: Digital AMPS
DCS: Digital cellular system
D-MCA: Digital multichannel access
DECT: Digital-enhanced cordless telephony
DQPSK: Differential quadrature phase-shift keying
ERMES: European Radio-Message System
ETS: European Telecommunications Standard
FDMA: Frequency-division multiple access
FFSK: Four-level frequency-shift keying
GFSK: Gaussian frequency-shift keying
GSM: Global System for Mobile Communications
GMSK: Gaussian-prefiltered minimum-shift keying
iDEN: Integrated Dispatch-Enhanced Network
IMBE: Improved MultiBand Excited
IS: Interim standard
JDC: Japan digital cellular
JDCT: Japan digital cellular telephone
JTC: Joint Technical Committee
LTP: Long-term prediction
MIRS: Multimedia Information-Retrieval Services
Mobitex: Mobile data system
Modacom: Mobile data communication
M16QAM: Multilevel 16-symbol quadrature amplitude modulation
MPT: Ministry of Posts and Telecommunications (United Kingdom)
NADC: North American Digital Cellular
OQPSK: Offset quadrature phase-shift keying
PACS: Personal-access communications system
PCN: Personal communications network
PCS: Personal communication services
PDC: Personal digital cellular
PHP: Personal HandyPhone
PHS: Personal HandyPhone system
PWT: Personal wireless telecommunications
RCR: Company and publication that cover cellular and mobile communication
RELP: Residual-excited linear prediction
TDD: Time-division duplexing
Tetra: Trans-European trunked radio
TFTS: Terrestrial flight-telephone system
TIA: Telecommunications Industry Association
TSB: Telecommunications Standards Board
VSELP: Vector-sum-excited linear predictive
WCPE: Wireless customer-premise equipment