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The Digital PCS Family of Standards

Digital PCS is defined by a family of voluntary standards that establish the compatibility and performance requirements for the air interface technology. Standards assist manufacturers, service providers, and end users to build, buy, and use products that provide mutually agreed upon features, functionality, and performance. Standards also facilitate the interoperability of products built by different manufacturers. With standards, the service provider and end user have more choices in products than would otherwise be the case, and manufacturers have access to more markets than otherwise. The Digital PCS family of standards includes IS-136 (now TIA/EIA-136), IS-137, IS-138, IS-641, IS-130, and IS-135, which this chapter summarizes. Eventually, all these standards will become parts of the TIA/EIA-136 standard.

3.1 Telecommunications Industry Association

The Telecommunications Industry Association (TIA) developed the Digital PCS family of standards. The TIA is a trade organization that operates in association with the Electronics Industry Association (EIA) to develop telecommunications standards for North America. Engineering committees of the TIA formulate standards through the efforts of both TIA member companies and nonmember participating companies. The TIA designates its engineering committees as TR committees. This is a holdover from the first TIA engineering committee, TR-8, originally known as the Transmitter Division (hence the letters *TR* from *transmitter*). TR-45, the Mobile and Personal Communications Standards engineering committee, develops the majority of cellular standards for North America. These include air interface standards such as EIA/TIA-553, IS-54, and TIA/EIA-136, and intersystem standards such as TIA/EIA-41. Different engineering subcommittees formulate standards for differing air interface technologies and the intersystem interface. Within TR-45, engineering subcommittee TR-45.3, Time Division Digital Cellular Technology, maintains the Digital PCS air interface standards. Subcommittee TR-45.2, Cellular Intersystem Operation, maintains the TIA/EIA-41 standard for intersystem signaling used with Digital PCS.

TR-45.3 is organized into working groups focused on different aspects of the Digital PCS standards, as shown in Table 3.1. Working Group 2 is responsible for data services, including IS-130 and IS-135 circuit-switched data and 136+ packet data. Speech services are under the purview of Working Group 5. Working Group 5 standardizes vocoders such as IS-641. Working Group 6 is responsible for all aspects of the DCCH, as well as the signaling on the TIA/EIA-136 control and traffic channels. Each working group works and meets independently of each other and coordinates their activities at the engineering subcommittee level.

Working groups are contribution-driven. A contribution is a written recommendation from a working group participant, with background material to justify the recommendation. The working group must reach consensus on the recommendation for it to be adopted. A new standard or a revision to a standard normally begins with a contribution from one

Table 3.1
TR-45.3 Working Groups

TIA TR-45.3 Working Groups	Responsibility	Example of Standard Developed
TR-45.3.2	Data services	IS-130/135
TR-45.3.5	Speech services	IS-641
TR-45.3.6	Digital control channel	TIA/EIA-136

or more participants in TIA. The development of a new feature or service within a standard also begins with a contribution.

There are three stages to the development of standards text for new features or services, called by the somewhat uninspired names of stage 1, stage 2, and stage 3. Stage 1 is a description of a feature or service from the user's point of view. It describes what the proposed feature or service will do for the user. Stage 2 is a description of a feature or service as implemented in the network. It describes the interaction of different elements in the cellular network to provide the feature or service to the end user. Stage 3 is a detailed description of the procedures, protocols, physical characteristics, and performance required to provide the feature or service to the end user. It is the stage 3 description that becomes standards text. Stage 1 should be completed before stage 2, and stage 2 before stage 3. This guarantees thorough definition of a new feature or service and increases the likelihood of its implementation.

Approved stage 3 text is added to the adopted baseline text for the standard. The baseline text is frozen when the working group determines by consensus that all required new material has been approved. Verification and validation (V&V) comes next, in which the proposed standards text is reviewed for technical and editorial accuracy. Discrepancies in the proposed standard are identified and corrected. The V&V process is an internal review conducted before submitting the proposed standard for approval. The proposed standard is submitted for ballot once the V&V process is complete.

3.2 Interim Standards and American National Standards

A TIA standard may be published as an Interim Standard when time is of the essence due to an urgent industry need for a technology. The TIA releases an Interim Standard for industry use for a limited period of time. It may eventually become an American National Standard if balloted and approved by the American National Standards Institute (ANSI). A TIA Interim Standard is identified by the designator TIA/EIA/IS, followed by a hyphen and a numeral. When an Interim Standard becomes an American National Standard, the designator is changed to ANSI/TIA/EIA and the IS designator is dropped. Often, the TIA/EIA designator is left off when discussing an Interim Standard—for example, IS-136. Similarly, the ANSI designator is often left off when discussing a national standard. For example, the IS-54 standard has become an American National Standard with the designation TIA/EIA-627. Most people still know this standard as IS-54, however. The AMPS standard EIA/TIA-553 is an American National Standard that was formulated before the TIA was spun-off from the EIA, hence the acronyms are reversed.

After a proposed Interim Standard is formulated, a letter ballot is distributed to TIA member organizations. Organizations may vote yes, yes with comments, or no with comments. The engineering subcommittee attempts to resolve any negative ballot comments received, and reballots the proposed standard if technically substantive change result from comment resolution. A default ballot may be issued if limited technical changes have been made to the proposed standard to resolve a negative ballot comment. The default ballot results must show a consensus in favor of adoption of the proposed standard. If a ballot results in adoption of the proposed standard, the TIA confirms that it has been prepared according to guidelines and publishes it as an Interim Standard.

The value of an Interim Standard is the rapid approval process, primarily due to the limited requirements for ballot review. However, an Interim Standard only has a lifetime of three years. It behooves the TIA formulating body to eventually convert the Interim Standard to an American National Standard by presenting it for approval by ANSI. ANSI requires a broader group of ballot reviewers, a longer ballot cycle, and a more formal ballot resolution process.

3.3 The Digital PCS standards

The Digital PCS family of standards, summarized in Table 3.2, originated as Interim Standards in TIA Engineering subcommittee TR45.3. IS-136 grew out of the IS-54 standard and defines the control, traffic, and voice channels used in Digital PCS. IS-137 and IS-138 specify the minimum performance requirements for Digital PCS mobiles and base stations, respectively. IS-641 defines a high-quality vocoder used in Digital PCS. The circuit-switched data standards for Digital PCS are defined by IS-130 and IS-135.

3.3.1 IS-136

IS-136 (now TIA/EIA-136) describes the attributes of the channels used in Digital PCS, from the physical layer through the network layer. By far, the largest section of the standard is the part describing the DCCH, undoubtedly because the DCCH is the most complex of the Digital PCS channels. The definition of the DCCH is also the primary difference between IS-136 and IS-54, apart from the new vocoder defined by IS-641. Because IS-136 builds on IS-54, most of the standards text describing the ACC, AVC, and DTC remains in the IS-54 format. The format of the standards text describing the DCCH is much different, however. Three major sections of IS-136 describe the DCCH, with each section devoted to one of the layers of the IS-136 protocol. This makes it easier for implementers of the standard to focus on the parts they need to understand. For example, an RF designer needs to focus on the physical layer of IS-136. The link layer of IS-136 is the major focus of a DSP designer. Call processing and user interface software designers concentrate on the network layer.

The first version of IS-136, called Revision 0, simply adds the DCCH to the IS-54 control, voice, and traffic channels. The new features in Revision 0 of IS-136 include sleep mode, short message service, and nonpublic service. Revision A to IS-136 adds dual-band 800-MHz and 1,900-MHz support, call setup and handoff for the IS-641 vocoder, over-the-air activation, calling name presentation, and support for full-rate asynchronous data and fax. 136+ is the next revision to IS-136 and adds additional teleservice capability, intelligent roaming, a more robust and higher fidelity voice service, and packet data.

Table 3.2
Summary of the Digital PCS Family of Standards

Designation	Title	Content
IS-136	TDMA Cellular/PCS—Radio Interface—Mobile Station-Base Station Compatibility Standard	Air interface requirements for the digital control channel, analog control channel, digital traffic channel, and analog voice channel used in Digital PCS
IS-137	TDMA Cellular/PCS—Radio Interface—Minimum Performance Standards for Mobile Stations	Minimum performance requirements for 800-MHz and 1,900-MHz Digital PCS mobile stations
IS-138	TDMA Cellular/PCS—Radio Interface—Minimum Performance Standards for Base Stations	Minimum performance requirements for 800-MHz and 1,900-MHz Digital PCS base stations
IS-641	TDMA Cellular PCS—Radio Interface—Enhanced Full-Rate Speech Codec	Description of a 7.4-Kbps ACELP vocoder and associated forward error correction for use with Digital PCS
IS-130	TDMA Cellular/PCS—Radio Interface—Radio Link Protocol 1	Definition of a radio link protocol used to asynchronously transport data across an IS-136 radio interface
IS-135	TDMA Cellular/PCS—TDMA Services—Async Data and Fax	Definition of the network protocol used to asynchronously transport data across and IS-136 radio interface

IS-136 Revision A is the same as ANSI/TIA/EIA-136, and 136+ is the same as ANSI/TIA/EIA-136-A. This might appear confusing, but only because of the timing associated with converting IS-136 to an American National Standard. IS-136 Revision A was the most recently adopted

version of IS-136 when the three-year time limit on an Interim Standard expired. Because 136+ was not ready for ballot, TR-45.3 chose to submit IS-136 Revision A for ANSI ballot. All revisions to the standard after the adoption of ANSI/TIA/EIA-136, including 136+, are subject to the full ANSI ballot process and become revisions to the ANSI standard.

3.3.2 IS-137 and IS-138

IS-137 defines the minimum performance requirements for Digital PCS mobiles operating at 800 MHz and at 1,900 MHz. These minimum performance requirements fall into three categories: receiver, transmitter, and environmental. For each minimum requirement, the requirement is defined, the method of measurement is presented, and the minimum standard is identified. IS-137 includes receiver minimum standards for frequency coverage and acquisition time, demodulation, receive audio frequency response, receiver sensitivity, adjacent and alternate channel desensitization, protection against spurious response, bit error rate, protection against multipath, and signal strength measurement accuracy. The standard includes transmitter minimum requirements for frequency stability, carrier switching time, power output, power transition time, modulation type and stability, transmit audio frequency response, limitation of emissions, and time alignment. The environmental requirements for the mobile in terms of temperature, power supply voltage, humidity, vibration, and shock are also defined in IS-137.

The companion standard to IS-137 for Digital PCS base stations is IS-138. IS-138 contains base station receiver, transmitter, and environmental requirements, similar to IS-137. Environmental requirements for the base station are only included for temperature, power supply voltage, and humidity. Unlike mobiles, vibration and shock requirements are not defined for base stations because they are typically shielded from these conditions.

IS-137 and IS-138 are supporting standards to IS-136. They provide mobile and base station manufacturers with minimum performance requirements for the implementation of IS-136. A physical or link layer change to IS-136 often necessitates a change to IS-137 and IS-138. IS-137 Revision 0 and IS-138 Revision 0 only contain requirements for 800-MHz operation. Revision A to these standards adds requirements

for 1,900-MHz mobile and base station operation. Minor changes are also made in Revision A of IS-137 and IS-138 to accommodate the use of the IS-641 vocoder.

3.3.3 IS-641

IS-641 describes the ACELP vocoder that replaces the VSELP vocoder used in IS-54. A detailed description of the IS-641 voice encoder and decoder is provided in the standard, along with a description of the channel encoder and decoder used to provide error protection to the IS-641 coded voice. An example bad frame masking algorithm is also described in IS-641. This algorithm describes an example of the processing that can be used on decoded speech to make it more intelligible when speech frames have been corrupted by RF channel impairments. IS-641 also describes a bit exact software representation of the voice encoder and decoder, which must be used in Digital PCS mobiles. This guarantees that all Digital PCS mobile stations operate on user speech the same way. Base stations are not required to use a bit exact form of the IS-641 vocoder, however. Test vectors are included for the bit exact representation of the voice encoder and decoder to ensure that the standard is implemented as specified.

IS-641 is another supporting standard to IS-136. IS-136 defines the physical layer that the IS-641 vocoder uses. IS-136 also defines the protocol used between the mobile and base station to set up calls and perform handoffs with the IS-641 vocoder. Revision A of IS-641 adds *discontinuous transmission* capability to the vocoder. With discontinuous transmission, voice activity detection is used to identify pauses in user speech, and only actual speech samples are coded and transmitted. This differs from typical vocoder implementations in which pauses in user speech are processed and transmitted as if they were actual speech segments. Discontinuous transmission allows the mobile to turn off its transmitter for a longer period of time during a conversation, thereby decreasing current drain and increasing talk time. Also added in Revision A to IS-641 is *comfort noise*. Comfort noise parameters can be transmitted from the voice encoder to fill in the silent gaps caused by discontinuous transmission. This can increase the perceived quality of the conversation.

3.3.4 IS-130 and IS-135

IS-130 and IS-135 are companion standards that require portions of IS-136 to be implemented for them to be used. IS-130 is the link layer that is used with the IS-135 network layer to provide asynchronous data and fax service on an IS-136 digital traffic channel. IS-130 defines a radio link protocol, RLP1, which includes link establishment, link supervision, acknowledged data transport, unacknowledged data transport, data qualification, data compression, encryption, and flow control. IS-135 defines a network protocol for asynchronous data and fax transport that includes call setup, supervision, clearing, AT command handling, user data transport, online command signaling, break signaling, and signaling leads for the service. IS-135 requires a link layer protocol such as IS-130 and uses the IS-136 call control for call setup, supervision, and clearing. With IS-130 and IS-135, asynchronous data and fax service can be provided over a half-, full-, double-, or triple-rate digital traffic channel. This allows for a range of data rates based on user need and mobile and system capabilities. IS-130 and IS-135 are the subjects of Chapter 13.

3.3.5 TIA/EIA-136

The American National Standard TIA/EIA-136 will merge the Digital PCS family of standards into a single standard with multiple parts. Working Group 6 of TR-45.3 restructured IS-136 and incorporated the remaining family of Digital PCS standards into one to make the Digital PCS standard easier to use, track, and revise. Table 3.3 summarizes the parts of TIA/EIA-136. The benefits of the multipart standard can be observed by considering the TIA/EIA-136-7XX parts, which define the Digital PCS teleservices. Under TIA/EIA-136, a new teleservice can be developed and the standard for that teleservice can be balloted without requiring the balloting of any other parts of the Digital PCS standard. Mobile and teleservice server software developers can pull out this small part of the standard and develop the software to support the teleservice without having to wade through information not of use to them for the task at hand.

Table 3.3
TIA/EIA-136 Parts

Part Number	Title
TIA/EIA-136-000	List of Parts
TIA/EIA-136-0XX	Miscellaneous Information
TIA/EIA-136-009	Introduction
TIA/EIA-136-010	Optional Mobile Station Facilities
TIA/EIA-136-020	SOC, BSMC, and Other Codes
TIA/EIA-136-1XX	Channels
TIA/EIA-136-100	Introduction to Channels
TIA/EIA-136-110	RF Channel Assignments
TIA/EIA-136-121	Digital Control Channel Layer 1
TIA/EIA-136-122	Digital Control Channel Layer 2
TIA/EIA-136-123	Digital Control Channel Layer 3
TIA/EIA-136-131	Digital Traffic Channel Layer 1
TIA/EIA-136-132	Digital Traffic Channel Layer 2
TIA/EIA-136-133	Digital Traffic Channel Layer 3
TIA/EIA-136-140	Analog Control Channel
TIA/EIA-136-150	Analog Voice Channel
TIA/EIA-136-2XX	Minimum Performance
TIA/EIA-136-200	Introduction
TIA/EIA-136-210	ACELP Minimum Performance
TIA/EIA-136-220	VSELP Minimum Performance
TIA/EIA-136-270	Mobile Stations Minimum Performance
TIA/EIA-136-280	Base Stations Minimum Performance
TIA/EIA-136-3XX	Data Services
TIA/EIA-136-300	Introduction
TIA/EIA-136-310	Radio Link Protocol-1
TIA/EIA-136-320	Radio Link Protocol-2
TIA/EIA-136-330	Packet Data
TIA/EIA-136-350	Async Data/Fax
TIA/EIA-136-4XX	Vocoders
TIA/EIA-136-400	Introduction
TIA/EIA-136-410	ACELP
TIA/EIA-136-420	VSELP
TIA/EIA-136-430	US1
TIA/EIA-136-5XX	Security
TIA/EIA-136-500	Introduction

Part Number	Title
TIA/EIA-136-510	Authentication, Encryption of Signaling Information/User Data, and Privacy
TIA/EIA-136-511	Messages Subject to Encryption
TIA/EIA-136-6XX	Teleservice Transport
TIA/EIA-136-600	Introduction
TIA/EIA-136-610	R-DATA/SMDPP Transport
TIA/EIA-136-620	Teleservice Segmentation and Reassembly
TIA/EIA-136-630	Broadcast Teleservice Transport
TIA/EIA-136-7XX	Teleservices
TIA/EIA-136-700	Introduction to Teleservices
TIA/EIA-136-710	Short Message Service—Cellular Messaging Teleservice
TIA/EIA-136-720	Over-the-Air Activation Teleservice
TIA/EIA-136-730	Over-the-Air Programming Teleservice
TIA/EIA-136-750	General UDP Transport Service
TIA/EIA-136-9XX	Annexes/Appendices
TIA/EIA-136-900	Introduction
TIA/EIA-136-905	Normative Information
TIA/EIA-136-910	Informative Information