

Brazilian Telecommunications Regulatory Framework and the Impacts on the Development of Broadband Radio Access Systems

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Abstract The introduction of new radio access technologies into the market has been accelerated in the last years, imposing an equally swift evolution of regulatory instruments aimed at adjusting telecommunication services to the new technological scenarios, e.g., by adequately allocating frequency bands for efficient spectrum utilization, and remodeling normative instruments for product certification. This chapter highlights the impacts of these regulatory sectors on systemic requirements, and points out new opportunities for developing broadband radio access system technologies taking the Brazilian regulatory scenario as a reference.

1 Introduction

The access to voice and data services over a broadband access network is first and foremost a public interest service granted under a public regime, or authorized under a private regime. However, it can also be characterized as the rendering of restricted interest services under a private regime when specific frequency bands are allocated to the different Limited Private Service (SLP). The SLP regime is intended to support the operational activities of companies, such as the electric

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power generation, transmission, and distribution sector (Smart Grid), the oil extraction, refinery and distribution sector, the urban and suburban mobility sector, as well as public security and disaster management operations.

In this chapter, the Brazilian Regulatory Framework for telecommunications services is adopted as basis for an analysis, as an effort to assess its impacts and highlight new opportunities for developing Fourth Generation (4G) and beyond broadband radio access system technologies. In order to provide a full understanding of the current scenario, some basic concepts and the evolution of the Brazilian regulatory framework are briefly described within each section.

International demand for a global and uniform distribution of frequency bands for fixed and mobile radio access systems has driven International Mobile Telecommunications (IMT) standardization activities since the 1980s. This broad concept, supported by technical recommendations and requirements, globally defines systemic interoperability issues (for both network and aerial interfaces), and services supported by certified technologies.

Within the IMT scope, and consequently based on a standards set from the National Agency for Telecommunications (Brazilian counterpart of the FCC, hereafter referred to simply as ANATEL) for the Brazilian territory, services supported by broadband radio access system have been defined. These comprise Public Switched Telephone Networks (PSTN), Personal Mobile Service (SMP), Multimedia Communication Services (SCM), for general (collective) interest applications, and SLP, with its different sub-modalities, for private applications.

Furthermore, several frequency bands have been defined, regulated, and allocated to the main collective interest services (fixed/PSTN and mobile/SMP) in the 824 MHz–2.2 GHz portion of the spectrum. The majority of this spectrum has been licensed to SMP service providers and is mainly used for voice services. This segment of the spectrum, although relevant for the sector, is out of the scope of this chapter, as it has already been thoroughly consolidated worldwide, and as such has no significant impact on emerging technologies under development.

The allocation of new frequency bands, for both public and private services, is a topic under constant discussion by ANATEL and the Ministry of Communications. Such frequency bands have a high potential for application in 4G and beyond broadband radio access technology, and are located for the most part in Ultra High Frequency (UHF) bands below 1 GHz, in some segments, in the 1.5 GHz range, and in certain specific bands such as 2.6 and 3.5 GHz. Therefore, special attention must be given to the evolution expected for these new frequency bands, especially regarding the technical requirements of services that occupy that same frequency band, sub-bands, or neighboring sub-bands. These issues pose a direct impact on the requirements for the coexistence of systems and services, and, consequently, on the requirements of new technologies and products under development.

Laboratory tests for ANATEL certification and approval of products are supported by a mixed structure of standards, resolutions, and technical requirements, which have been constantly modified to ensure they are adequate for new technologies and frequency bands. These regulatory standards must be analyzed in terms

of electromagnetic compatibility and electrical protection, and more specifically, in terms of requirements for base transceiver stations, terminals, and antennas.

The remainder of the chapter is organized as follows. In Sect. 2 an overview of the Brazilian Regulatory Framework is presented. In Sect. 3 the use of the radio frequency spectrum and band allocation issues are addressed, while in Sect. 4—products, and in Sect. 5—antennas the matter of product certification is addressed.

2 Regulatory Framework of Telecommunication Services

Telecommunication services are classified as collective interest services or restricted interest services.

2.1 *Collective Interest Services*

Collective interest services are those that are rendered under a public or private regime, and seek to meet collective needs indiscriminately. The only public service rendered under a federal concession is PSTN. SMP and SCM are authorized private services.

2.1.1 Public Switched Telephone Network

PSTN was first regulated under the name Public Phone Service (STP), by the Ministry of Communications Standard # 05 [1]. In 1998, Resolution # 73 [2] was issued, containing the basic regulations for telecommunication services. A month later, Resolution # 85 [3] was published with the first PSTN regulatory standards, under ANATEL's regulatory administration. The main difference in scope between Standard 05/79 and Resolution 85 is in the way services are provided. The first one regulated telecom services under the state-controlled regime, stipulating that “public phone services are provided nationwide by companies controlled by Telecomunicações Brasileiras S/A (TELEBRÁS) and by other companies and organizations with concession contracts in effect”. The second one regulated PSTN, specified that services were to be provided under “contracts or terms of concession, permission and authorization, signed between Service Providers and ANATEL”.

Still in 1998, ANATEL published Resolution # 78 [4], laying out guidelines for allocating frequency bands for Fixed Wireless Access Systems to provide PSTN services, a system known at the time as Wireless Local Loop (WLL). In 1999, Resolution # 146 [5] approved regulatory standards for WLL certification, while Resolution # 166 [6], also issued in 1999, regulated WLL system utilization. These were mainly supported by Cellular Mobile Service (SMC) networks,

currently SMP. In 2005, ANATEL published new regulatory standards for PSTN in Resolution # 426 [7]. This resolution increased the scope of PSTN service definitions, especially regarding accessibility, personal services, Significant Market Power, the ability to identify the origins and destinations of calls, the protection or suspension of privacy, the sharing of infrastructure, among other issues. Resolution # 426, issued in 2005, regulates PSTN until today.

2.1.2 Personal Mobile Services

In 1996, Law 9,295 [8], also known as Minimum Law, was passed, defining telecommunication services and their organization, as well as outlining the powers of the regulatory body. This law was the catalyzing element that triggered the beginning of competition in the mobile services sector, as the first private service providers began operating in Band B, while state-owned providers continued their Band A operations.

During this period, Land Mobile Services were known as SMC. The first regulatory standard for SMP, now supported by the General Communications Law (Law 9,472) [9], approved the guidelines for SMP deployment in Resolution # 235 [10]. Still in 2000, Resolution # 245 [11] and Resolution # 248 [12] were issued, establishing the SMP Master Authorization Plan. This set of three resolutions composed the initial framework for migrating SMC to SMP and increasing the number of authorized SMP service providers.

A relevant evolution took place in 2010, with the publication of Resolution # 550 [13], regulating Virtual Network SMP exploration (RRVSMP). Additionally, service quality was defined by the Master Quality Plan (PGMQ), published in Resolution # 317 [14] gauged by the quality indicators established in Resolution # 335 and measured in compliance with Resolution # 443 [15]. SMP is currently regulated by Resolution # 477 [16], supported by the Master Authorization Plan defined in Resolution # 321 [17] and gauged by PGMQ-SMP.

2.1.3 Multimedia Communication Services

Until August 2001, the transmission of multimedia communication data was supported by Special Limited Services (SLE), using the sub-modalities Specialized Network Services (SRE) and Specialized Circuit Services (SCE), as well as the Telecommunications Transport Network Services (SRTT), comprising Dedicated Line Services (SLD), Packet Switched Network Services (SRCP), and Circuit Switched Network Services (SRCC), all general (collective) interest services. In 2001, ANATEL published Resolution # 272 [18], defining SCM regulatory standards.

In 2003, ANATEL published Resolution # 328 [19], approving models for the Term of Authorization for SCM exploration, which could also be adapted for SLE and SRTT authorizations. Resolution # 614 [20], besides improving several

features used on an experimental basis during the first years of authorization, established the milestones for increasing widespread use of the SCM services.

2.2 Restricted Interest Services—Limited Private Services

The SLP regulatory framework has its origin in Law 4,117 [21], which established the Brazilian Telecommunications Code. Chapter 6 of this law defines limited services: “a limited service is that provided by stations not open to public correspondence to be utilized by Brazilian private citizens or companies. Such limited services include, security, regularity, orientation, and administration of transportation services in general, multiple destinations, rural services, and private services, to name some”. Not long after that, the first limited service and the SLP submodality were assigned.

Standard 13 [22] defines the characteristics of SLP and SLE and their submodalities: Private Mobile Services, Private Radio Call Services, Private Network Services and Private Radio-Taxi Services, Specialized Mobile Services, Specialized Circuit Services, Specialized Network Services, and Specialized Radio-Taxi Services.

In 2013, ANATEL published Resolution # 617 [23], which consolidated in a single regulatory standard the following definition: “SLP is a restricted interest telecommunications service, explored nationwide or worldwide under a private regime, taken by users themselves or rendered to a given group of users, selected according to criteria defined by the service provider, comprising multiple applications, including the data communication, audio and video signal communication, and voice and text communication, as well as capturing and transmitting Scientific Data related with the Exploration of the Earth by Satellite, Meteorology Assistance, Satellite Meteorology, Space Operations and Space Research”. This resolution revoked a large number of regulatory standards that had become enacted over the years.

3 Regulatory Framework for Frequency Band Allocation

This topic focuses on regulatory standards regarding the allocation of certain bands specifically strategic for the development of broadband radio access systems.

3.1 225–470 MHz Sub-Bands

Until recently, the sub-bands located in the 225–470 MHz UHF range had been used by several narrowband voice and telemetry services, especially

SLP and Private Mobile Limited Services (SLMP). In 2010, ANATEL published Resolutions # 555 [24], 556 [25], 557 [26], and 558 [27], reassigning frequency bands from 225 to 270 MHz, 360 to 380 MHz, 380 to 400 MHz, and 450 to 470 MHz, respectively. Resolutions # 555 and 558 stand out from the other regulatory standards since they assign sub-bands in the 250 and 450 MHz range, with wide channels able to handle broadband radio access systems operations. These resolutions partially replace the standards enacted by the Ministry of Communications in Decree 623 [28].

ANATEL launched Resolution # 558, which allocates the sub-bands from 451.5875 to 454 MHz, from 456.5875 to 459 MHz for airport SLP, and of Resolution # 446 [29], which regulates this service specifically. These sub-bands occupy part of the uplink sub-band allocated to PSTN, SMP, and SCM for broadband network access. The conditions for the coexistence of these services and airport SLP are defined in Resolution # 446, which defines a 10 km protected perimeter around all national airports identified in the resolution.

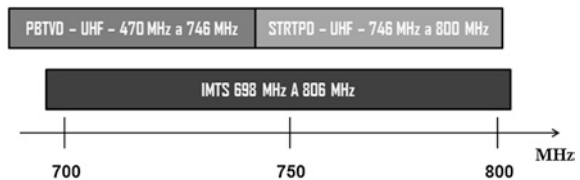
3.2 698–806 MHz Sub-Bands

The digitalization brought about by the deployment of the Brazilian Digital TV System (SBTVD) opened up the possibility for a more efficient use of the spectrum assigned to TV services. Moreover, the fact that the chosen digital transmission standard allows signals to be repeated isofrequentially (on the same channel), optimizing spectrum use. For a proper analysis of the current and future allocation of the 700 MHz frequency band, it is important to bear in mind the following issues:

- (a) The frequency band known as the 700 MHz band is located between the 698 and 806 MHz frequencies. Today, this band is allocated to Sound and Image Broadcasting Services (TV), occupying UHF channels 52–69;
- (b) The Basic Digital TV Plan (PBTVD) proposes allocating channels 14–59 (470–746 MHz) for DTV in Brazil;
- (c) Channels 60–68 (746–800 MHz) have been earmarked for Television and Public Digital Television Retransmission Services.

Figure 1 illustrates this issue within the scope of the digital divide to be obtained once the migration from analog-to-digital TV has been completed, scheduled for 2016.

Fig. 1 Analogue-to-digital TV migration



In their 2008 Radio Regulations edition [30], ITU-R allocated the 698–806 MHz range to IMT (mobile services). In 2009, Decree # 24 [31] approved the General Standard for Executing Public Digital Television Services, defining channels 60–68 (746–800 MHz) for this. In 2010, Decree # 276 [32] approved the Technical Standard for Executing Sound and Images Broadcasting Services and Television Retransmission with digital technology. According to the standard, the allocation of the 54–88 MHz sub-bands in Very High Frequency (VHF), channels 2–6, no longer existed; the allocation of sub-bands 174–216 MHz (VHF channels 7–13) and 470–800 MHz (UHF channels 14–68) was maintained; the 608–614 MHz sub-band, corresponding to channel 37, is internationally allocated to radioastronomy services on a primary basis; and 60–68 are exclusively for Television and Public Digital Television Retransmission Services.

ANATEL Resolution # 584 [33], in 2012, changed the Regulations for Channeling and Terms of Radio Frequency Use for SARC, RpTV, and CFTV, besides enacting other measures. Among these measures, Chap. 17 called for studies to be carried out until December 2012 to define future use of the radio frequency spectrum, especially the 698–806 MHz range. Decree # 681 [34], in 2012, established a Work Group to study conditions for using the radio frequency range of 698–806 MHz. Recommendation ITU-R M.1036-4 [35] reinforced the allocation of the 698–806 MHz range, indicated by WRC-2007, to IMT, as shown in Fig. 2.

The 1.5 GHz band was first assigned to fixed services in Resolution # 198 [36], which revoked Standard # 15, from 1994. This resolution established the frequency channeling and terms of use of the 1427–1452 MHz and 1492–1517 MHz bands for fixed service digital systems, with transmission capacity

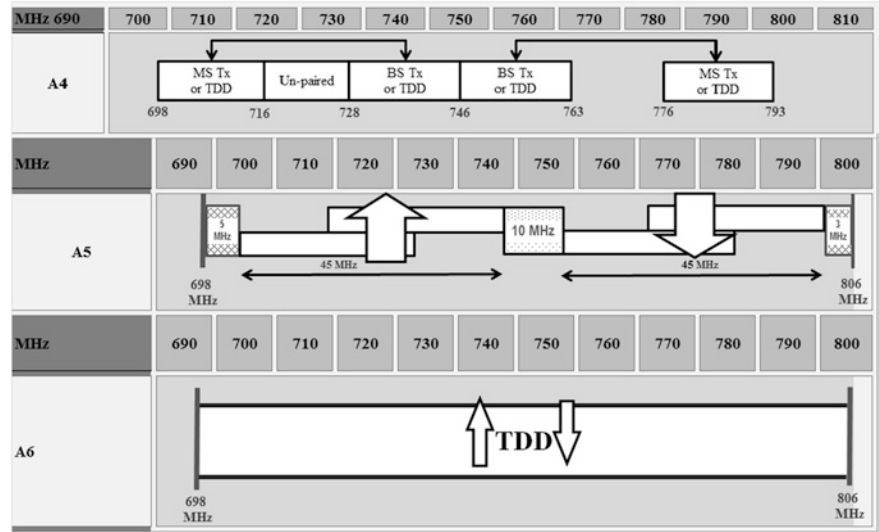


Fig. 2 Allocation of the 698–806 MHz range for IMT

MHZ	Anatel - PADFF			UIT-R RR-08		3GPP-ULTRA	
1425				1427-1429			
1430	1427			E, F, M			
1435	1452						
1440					1429-1452	1428-1448	
1445	Fixed S.				F, M	Lower Band	
1450	Res. 198					11 Japan	
1455		1452					1448-1463
1460		1472					Upper
1465		Telemetry					Band 21
1470		SMA	1452-1492	1452-1492			Japan
1475	1472	Res. 391	Mobile S.	F, M, B			
1480	1492		Res. 391				
1485						1476-1496	
1490	Not					Lower Band	
1495	Destined					11 Japan	
1500		1492			1492-1518		1496-1511
1505		1517			F,M		Upper
1510		Fixed S.					Band 21
1515		Res. 198					Japan
1520	Not			1518-1525			
1525	Destined			F,M, MS			
1530		1525					
1535		1544					
1540		All					
1545	1545						
1550	1555						
1555	All						

Fig. 3 Definition of frequency bands for the E-UTRA aerial interface

of 2×2 Mbps for point-to-point and point-to-multipoint applications. Later, Resolution # 391 [37], published in January 24, 2005, approved Regulations for the Terms of Radiofrequency Use in the 1452–1472 MHz range, assigned to air force mobile services, for Telemetry applications, on a primary basis, the 1452–1466 MHz radio frequency range, and on a secondary basis, the 1466–1472 MHz range, and assigned the 1452–1492 MHz radio frequency range additionally to mobile service, on a primary basis.

Figure 3 is a diagram portraying ANATEL’s allocation based on the two above-mentioned resolutions, on the ITU-R Radio Regulations 2008 issue, and on the 3GPP Forum’s definition of frequency bands for their E-UTRA aerial interface.

Based on this scenario, one can deduce that fixed services, PSTN and SCM in the case of Brazil, could use the two $25 + 25$ MHz segments from 1427 to 1452 MHz and from 1492 to 1517 MHz ranges for point-to-point and point-to-multipoint applications, while mobile services could use the 6 MHz segment between 1466 and 1472 MHz for TDD applications, where SMA-Telemetry would be allocated on a

Table 1 ANATEL SitarWeb system data

Service	MIN	MAX	ENL	%
12-Radio for Private Mobile Service	1429	1515	28	1.00
9-Limited Private Service	1429	1582	1127	24.00
46-Radio for Multimedia Communication Service	1429	1519	70	2.00
53-Radio for Personal Mobile Service	1429	1522.5	346	7.00
175-PSTN	1429	1526	3044	66.00
			4615	

secondary basis. However, 3GPP's definition of bands 11 and 21 compromises the utilization of the above-mentioned bands. That leaves only the 1518 and 1555 MHz sub-bands as possibilities for broadband access system allocation.

Several equipment manufacturers supply products for operation in this frequency range, called WiGrid, used by the WiMAX Forum. The technical specifications of these products indicate they are for use in the 1330–1530 MHz or 1350–1517 MHz frequency range. This segment of the spectrum is currently allocated to several services and according to the ANATEL SitarWeb [38] system's directory of granted licenses, 4,615 licenses have been distributed among PSTN, SLP, and point-to-point radio link licenses for SCM and SMP support (Table 1).

4 Regulatory Framework for Certification and Approval of Telecommunication Products

This section presents an overview of the context and the current stage of product certification in Brazil.

4.1 Classification of Telecommunication Products

For certification and approval purposes, telecommunication products are segregated in three categories, according to their applications and use:

- (a) Category I: Terminal equipment for use by the general public to access collective interest telecommunication services;
- (b) Category II: Equipment not included in the Category I definition, but that uses the radio electric spectrum to transmit signals, including antennas and all equipment characterized under specific regulations as restricted radiation radio-communication equipment;
- (c) Category III: Products that do not fit the definitions of Categories I and II, and need to be regulated to ensure the interoperability and reliability of the telecommunication support networks.

4.2 Magnetic Compatibility and Electrical Safety Requirements

In 2000, ANATEL published Resolution # 237 [39] and Resolution # 238 [40], approving Regulatory Standards for the Certification of Telecommunication Equipment regarding Electromagnetic Compatibility Aspects and regarding Electrical Safety Aspects, respectively. These resolutions were revised and updated in 2006 and 2009. In 2006, ANATEL published Resolution # 442 [41] approving Regulatory Standards for the Certification of Telecommunication Equipment regarding Electromagnetic Compatibility Aspects and revoked Resolution # 237. In 2009, ANATEL published Resolution # 529 [42], approving Regulatory Standard for the Certification of Telecommunication Equipment regarding Electrical Safety Aspects and revoked Resolution # 238. In general, all telecommunication equipment must meet the compatibility and safety requirements defined in Resolutions # 442 and 529, respectively.

Another caveat to be made to EMC and Safety requirements is on its applicability on the respective Resolutions' (BS and Terminal) Previous regulations—Technical Requirements and Test Procedures Applicable to Telecommunication Products Certification in Category I and II, respectively, from April 16 and 17, 2013 [43, 44]. It was a directive from ANATEL to protect the public in general, not including certain regulatory tests in the framework of the equipment intended for Operators' Companies, being more strict for Category I equipment (Terminals—Estação Terminal de Acesso and Telefone Móvel Celular) when compared to the equipment classified as Category II (Base Stations—Transceptores para Estação Rádio Base). Until 2015 the mandatory tests for Terminals included the full execution of the Amendments to the Resolutions # 442 (EMC) and # 529 (Safety), while Base Stations were tested only for Emission aspects (Title II of Annex to Resolution # 442), not including Immunity tests and three paragraphs in the Annex to Resolution # 529, when applicable.

This understanding was recently changed and in the new issue—Technical Requirements and Test Procedures Applicable to Telecommunication Products Certification in Category I and II, respectively, from June 1 and April, 2015 [45, 46]—the EMC and Safety tests (Annexes to the Resolutions # 442 and # 529) are demanded in the full, both for Terminals and Base Stations.

4.3 Base Transceiver Stations and Terminal Requirements

In April 2004, ANATEL published Resolution # 361 [47], approving the Standard for the Certification and Approval of Analogue FM and PM Mono-channel Transmitters and Transceivers Operating in the Under-1 GHz Frequency Range. This resolution replaced Standard 01/89—Technical Specifications Standard for Mono-channel Radio Equipment in the 30–470 MHz range with Angular

Modulation—and Standard 02/89—Measurement Method Standard for Mono-channel Radio Equipment in the 30–470 MHz range with Angular Modulation. For lack of specific regulatory standards for the certification and approval of under-1 GHz digital transceivers, this standard was adapted to delineate the technical requirements for radio access equipment in process of development, production, and commercialization.

Still in the same year, ANATEL published Resolution # 368 [48] to attend to the demand for the certification of WLL products for PSTN services. This resolution defined the general and specific technical requirements to be demonstrated in the evaluation of the conformance of digital transmitters and transceivers (CDMA and TDMA, including GSM) for fixed services in point–multipoint applications operating in over-1 GHz frequency ranges. In 2006, ANATEL published Resolution # 433 [49], approving the Standard for the Certification and Approval of Transmitters and Transceivers in Base Transceiver Stations (BTS) and PSTN Repeater Stations. This resolution affects BTS equipment operating in the 400, 1900, and 3500 MHz ranges, with CDMA or TDMA technology, including GSM.

No specific regulatory standards were found to support the process of testing and certifying OFDM/OFDMA equipment for base transceiver stations and terminals. However, the document describing the technical requirements and test procedures for category I telecommunication products, updated on April 16, 2013, and available on ANATEL's web site does indicate a sub-set of technical requirements defined by the 3GPP Forum for the E-UTRA (Long Term Evolution—LTE) aerial interface, applicable for a SMP Access Terminal with this technology, that is: 3GPP TS 36.521-1 V9.5.0 (2011-06) 3GPP; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) conformance specification Radio transmission and reception Part 1: Conformance Testing; (Release 9), in items 6.2.2–6.6.3.1.

The current regulatory scenario for product certification can be summarized as follows, according to the major globally standardized wireless technologies:

- (1) WiMAX (IEEE 802.16) equipment are classified as Digital Transceptor (Transceptor Digital), fitting into Category II. This understanding is valid for both Base Stations and Customer Premises Equipment.
- (2) Wi-Fi (IEEE 802.11) equipment are classified as Restricted Radiation Equipment (Equipamento de Radiação Restrita), also in Category II.
- (3) 4G (LTE) equipment, as well as the legacy mobile technology (2G, 3G), are classified as:
 - (a) BS—BTS—Category II.
 - (b) Customer Premises Equipment (CPE)—Access Terminal Station (ETA), Category I.
 - (c) Handsets and Tablets—Cellular Mobile Telephone (Telefone Móvel Celular), Category I.

Additionally new resolutions have been issued for different technologies and frequency bands, as well as the addition of more recent 3GPP standards references for LTE equipment in the regulatory framework, focusing essentially on the

protection of the electromagnetic spectrum (the tests demanded usually focus on the Transmission characteristics, not covering the reception).

Within this scenario, the new Technical Requirements and Test Procedures Applicable to Telecommunication Products Certification in Category I and II for Base Station and Terminal operating on 4G technology are the following:

Base Station

Category: II

Product: Base Station Transceiver

- (1) Annex to Resolution # 554 [50]—December 20, 2010—Standard for Certification and Homologation of Transmitters and Transceivers for Base Stations and Repeaters, applicable in full;
- (2) Annex to Resolution # 359 [51]—April 1, 2004—Standard for Certification and Homologation of Digital Transmitters and Transceivers for the STFC in Point-to-Multipoint Applications under 1 GHz, applicable in full;
- (3) Annex to Resolution # 492 [52]—February 19, 2008—Standard for Certification and Homologation of Digital Transmitters and Transceivers for the STFC in Point-to-Multipoint Applications above 1 GHz, applicable in full;
- (4) LTE Technology: 3GPP TS 36.141 V9.8.0 (2011-06) 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (EUTRA); Base Station (BS) conformance testing (Release 9) [53], items 6.2, 6.4, 6.6.1, 6.6.2, 6.6.3.5.2, 6.6.4.5.2, and 7.7, the last one, although referring to a Transmitter test on the issue of Spurious Emission from the Receptor.

Access Terminal—CPE

Category: I

Product: Access Terminal Station

- (1) Technology LTE: 3GPP TS 36.521-1 V9.5.0 (2011-06) 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) conformance specification Radio transmission and reception Part 1: Conformance Testing; (Release 9) [54], items 6.2.2, 6.2.3, 6.2.5, 6.3.2, 6.3.4.1, 6.5.1, 6.5.2.1, 6.5.2.2, 6.5.2.3, 6.6.1, 6.6.2.1, 6.6.2.3, 6.6.3.1;
- (2) Annex to Resolution # 359—April 1, 2004—Standard for Certification and Homologation of Digital Transmitters and Transceivers for the STFC in Point-to-Multipoint Applications under 1 GHz, applicable in full;
- (3) Annex to Resolution # 492—February 19, 2008—Standard for Certification and Homologation of Digital Transmitters and Transceivers for the STFC in Point-to-Multipoint Applications above 1 GHz, applicable in full.

For both cases, CPEs and Base Stations, there are requirements specific for legacy technology such as GSM, TDMA, CDMA, WCDMA/HSDPA/HSUPA, etc.. not covered in this chapter, applicable when necessary.

EMC and Safety regulatory framework covered in item 3.2.

5 Antenna Requirements

In 2004, ANATEL published Resolution # 366 [55], approving the Standard for the Certification and Approval of Linear Antennas and replaced Standard # 08/95—Minimum Linear Antenna Radiation Characteristics. In 2004, ANATEL also published Resolution # 372 [56], which approved the Standard for the Certification and Approval of Directional and Omnidirectional Antennas. In 2013, ANATEL published Resolution # 609 [57], approving the Standard for the Certification and Approval of Antennas for Use in Point-to-Point Applications and Resolution # 610 [58], approving the Standard for the Certification and Approval of Antennas for Use in Bidirectional Point-to-Area Applications. This standard applies to antennas in operation in bidirectional point-to-area systems for fixed and mobile terrestrial services, for the 138 MHz to 40.5 GHz bands, with gain equal to or above 8.5 dBi for omnidirectional antennas and above or equal to 9.5 dBi for all other antennas. Furthermore, the standard rules that telecommunication terminals equipped with gain antennas lower than 8.5 dBi, in the case of omnidirectional antennas, and 9.5 dBi, in the case of all others, must meet the requirements of the certification standards and of the services they are designated for.

6 Conclusions

Based on what has been set forth throughout this chapter, it can be observed that, regarding telecommunication services, PSTN had its moment of wireless technology application when WLL systems were deployed. This initiative occurred in a specific scenario, when PSTN and SMP service providers, during the SMC period, were separate companies and even competitors. Today, the vast majority of service providers own licenses for PSTN, SMP, and more often than not, for SCM as well.

SCM, in turn, is an important tool for the operation of public policies aiming to universalize broadband access through small- and medium-sized private carriers. Another publication, Resolution # 617/2013, consolidated SLP definitions in a single regulatory standard, causing a major impact on services rendered by public and private organizations.

Thus, if we take into consideration the strategies for the development of 4G and beyond broadband radio access technology systems in Brazil, the following impacts and opportunities can be highlighted:

- (a) PSTN: Wireless broadband access system represents an important competitive tool for PSTN service providers, allowing them to launch new market strategies. However, the systemic requirement must ensure the exclusive requirements of these public general (collective) interest services, that is, the universality and continuity of such services;
- (b) SMP: Mobile broadband access technology is naturally applicable to the SMP access networks of SMP service providers. Regarding its systemic requirements,

special attention must be paid to the issues of network sharing and virtualization, essential tools for compliance with recent regulatory standards and for supporting the exponential growth of users and traffic, especially data;

- (c) SCM: As with PSTN, a network access platform with 4G technology is an important market entry tool, giving small- and medium-sized service providers a strategic competitive edge. Regarding its systemic requirements, special attention must be paid to the issue of network scalability and total cost of ownership, critical for the feasibility of small- and medium-sized companies' business plans when attempting to penetrate competitive markets;
- (d) SLP: The need for applications to support the various SLP operation modalities opens up an entire universe of niche opportunities for 4G and beyond technologies. In this case, special attention must be given to the regulatory trends triggered by Resolution # 617, which consolidated the various limited services under a unified regime, and to the impacts of future termination of the allocation and assignment of frequency bands to the different SLP modalities. This refarming began with the 4.9 GHz band and with the VHF and UHF sub-bands located between 215 and 470 MHz. Thus, future specifications are expected to define modular and flexible requirements for aerial interfaces currently under development, allowing them to be quickly adjusted to the new SLP applications.

As for the assignment of frequency bands in Brazil, one can observe from the contents of this chapter that the coordination of the radio frequency spectrum usage by services operating on a primary basis is not a simple task. To make things worse, the radio electric spectrum is a scarce public natural resource, that historically has been inefficiently provisioned. Due to the current state of spectrum saturation, several complex issues of coexistence among neighboring systems have begun to sprout up, usually caused by new co-channel systems, or systems operating in adjacent channels, with existing systems, that fail to meet the requirements needed for coexistence. For the frequency bands and systems analyzed in this chapter, the following conditions are critical for coexistence:

- (a) 250 MHz band: The 225–270 MHz frequency range is prone to suffer and generate interference in narrow-band limited services operating in neighboring sub-bands, and in the sound and image broadcasting services (TV), operating in the high VHF segment, between 174 and 216 MHz (channels 7–13);
- (b) 450 MHz band: The 451–458 MHz and 461–468 MHz frequency range are prone to suffer and generate interference in narrow-band limited services and auxiliary broadcasting services operating in neighboring sub-bands, and in the sound and image broadcasting services (TV), operating in the UHF segment, above 470 MHz (channels 14–59);
- (c) 700 MHz band: The 698–806 MHz frequency range is prone to suffer and generate interference in narrow-band limited services and auxiliary broadcasting services operating in neighboring sub-bands, and in the sound and image broadcasting services (TV), operating in the UHF segment, between 470 and 746 MHz (channels 14–59);

- (d) 1500 MHz band: New point-to-area systems using part of the 1427–1555 MHz range are not likely to suffer or generate interference in the point-to-point and point-to-area systems currently licensed for these frequencies. However, it has been proven that the new point-to-area systems operating in these segments of the spectrum and GPS systems cause strong interference between themselves.

Several opportunities exist for developing 4G and beyond technologies for radio access systems, especially for niche applications in frequency bands whose provisions have been reformulated to meet the needs of these new applications. In such cases, special attention must be paid to the air interface specifications, in order to mitigate coexistence issues with pre-established neighboring systems.

Finally, regarding the requirements for certification and approval, it can be observed that the set of standards regulating telecommunication products for their certification and approval can be grouped into three categories in terms of their compliance with new technology and the frequency bands assigned to 4G and beyond radio access systems, as follows:

- (a) The requirements for electromagnetic compatibility and electrical protection are the same for all telecommunication equipment and are consolidated and consistent;
- (b) The requirements for antenna approval have been updated recently and are compliant with the latest international standards and adequate for the newest broadband radio access systems;
- (c) The regulatory standards for the certification and approval of base transceiver stations and access terminals, on the other hand, still need to be updated, or even created, to meet the needs of 4G systems and coexistence among systems.

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