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Radiocommunication Sector of ITU

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(10/2010)

The transition to digital television and its impact on the unprotected use by the radio astronomy service of bands used for terrestrial television broadcasting

RA Series

Radio astronomy

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REPORT ITU-R RA.2195

The transition to digital television and its impact on the unprotected use by the radio astronomy service of bands used for terrestrial television broadcasting

(2010)

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1 Introduction

Television has become a fundamental form of communication in every region of the world. Its utility as a source of news, entertainment, and emergency information has been evident since its inception more than 60 years ago. Presently providing coverage to a global population numbering in the billions, terrestrial television broadcasting is one of the most ubiquitous uses of the radio spectrum.

The radio astronomy service does not share any allocations with terrestrial television broadcasting; however, such broadcasts generally occupy spectrum that is extremely important to low-frequency astrophysics and the observation of red shifted neutral hydrogen (HI) arising from early epochs in the formation of the universe. To date, radio astronomers have made use of TV bands to conduct observations, in accordance with No. 4.4 of the Radio Regulations (RR).

At the present time, many countries are transitioning from analogue to digital television broadcast standards (see Fig. 1), and some are also revising their broadcast allocations to recover spectrum that is expected to be freed up by the so-called “digital dividend”. Some aspects of the digital transition are expected to result in a reduction in the ability of radio astronomers to make use of the terrestrial television broadcast bands for observations that are currently conducted on an unprotected basis (see Fig. 2). Some aspects may improve the ability to make passive observations in the TV bands.

FIGURE 1

Distribution of planned digital TV transition, by technology.
Areas in gray have no current plans for digital TV transition

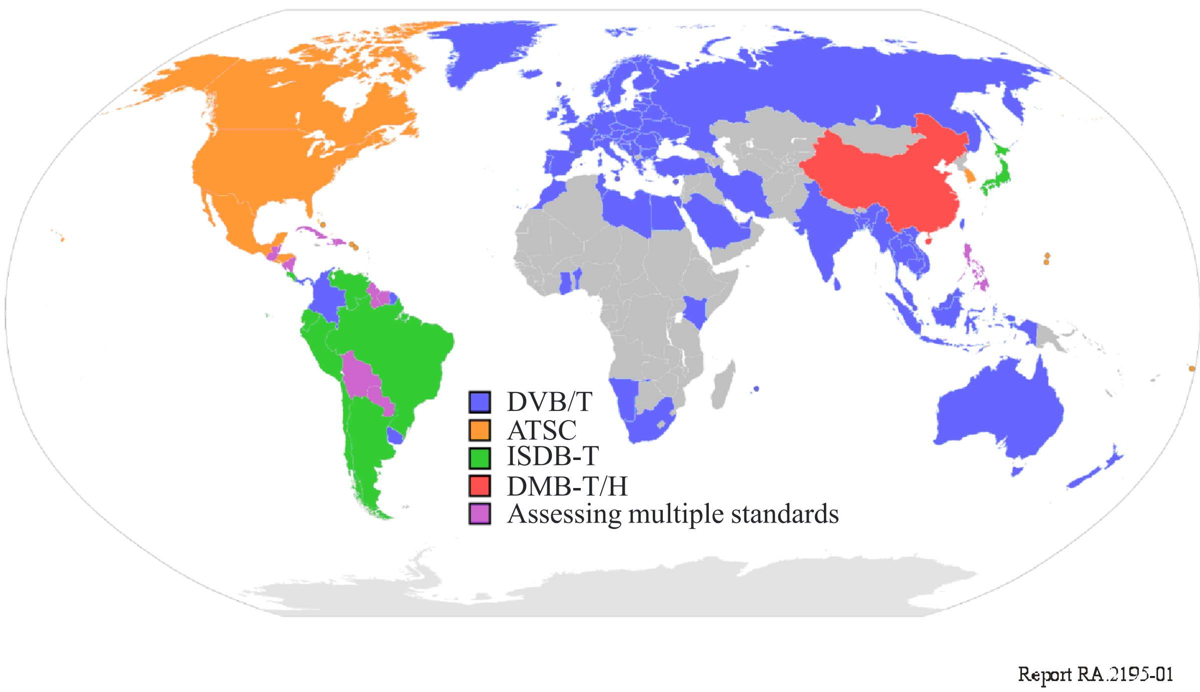
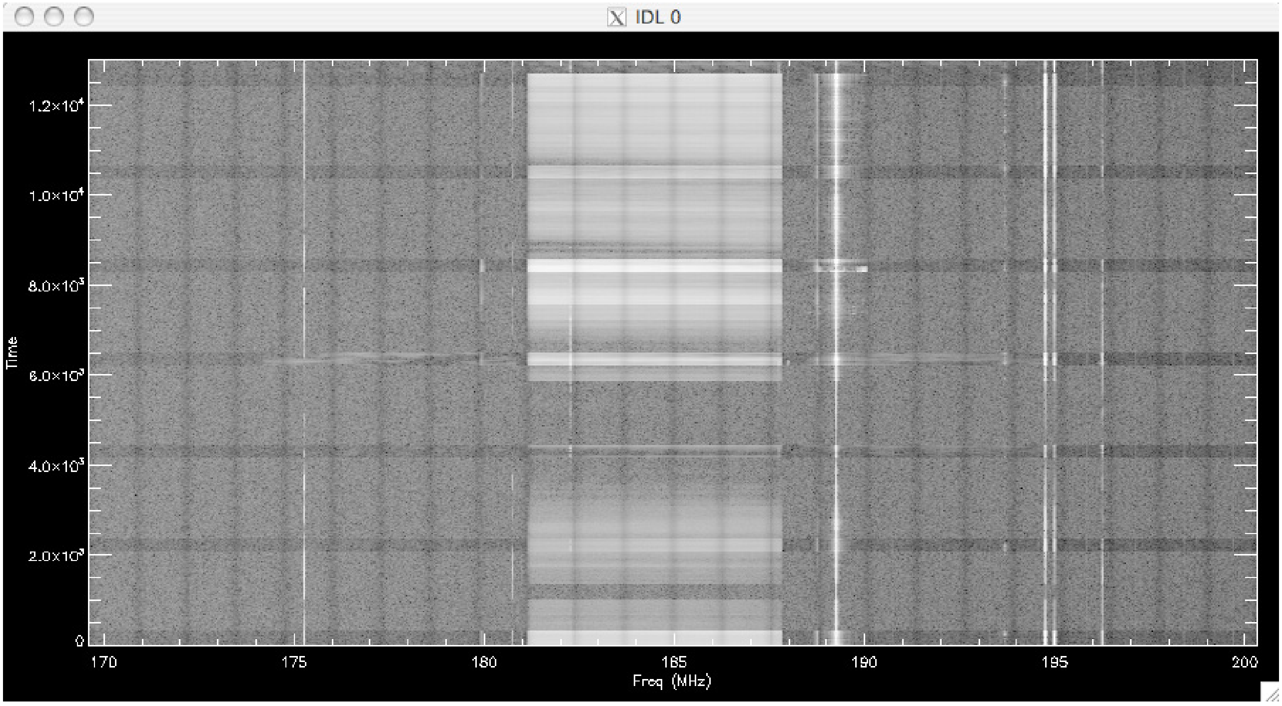


FIGURE 2

An example of the impact of digital TV signals compared to analogue TV. The spectra were obtained at a radio astronomy site during a brief period of highly enhanced propagation. The TV signals are originating from approximately 290 km away. The digital signal from 181-188 MHz "fills" the spectrum much more substantially than the analogue TV signals occupying 174-181, 188-195, and 195-202 MHz, whose spectra are concentrated in discrete video, chrominance, and audio carriers



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Annex 1 summarizes the plans for the transition to digital television for several countries around the world with current radio astronomy programmes operating within bands used for terrestrial television broadcasting, and for countries of strategic importance to future radio astronomy stations presently under design and development that intend to utilize such bands. The impact of service rules for digital television on the use of the television broadcast bands for radio astronomy is discussed.

The material in this report is specific to the impact of the digital transition on the radio astronomy service. A more general introduction to the transition to digital TV is available in Report ITU-R BT.2140 – Transition from analogue to digital terrestrial broadcasting.

Annex 1

Transition from analogue to digital television broadcasting

The following sections summarize those aspects of the transition to digital television that may impact the opportunistic use of the television broadcast bands for radio astronomy.

1 Australia

1.1 Date of transition

The Australian Government has announced a programme to switchover from analogue to digital transmissions and that it will be "completing the switchover by 31 December 2013".

1.2 Frequency allocations and assignments

In the Australian Radiofrequency Spectrum Plan (ARSP) VHF bands I (45-70 MHz), II (85-108 MHz) and III (137-144/174-230 MHz) as well as UHF bands IV (520-582 MHz) and V (582-820 MHz) have a primary allocation to the broadcasting service.

Digital television has been planned for operation within existing allocated broadcasting services bands in bands III (174-230 MHz), IV (526-582 MHz) and V (582-820 MHz).

Australian terrestrial television broadcasting services have been planned on a 7 MHz channel raster in both VHF and UHF bands.

1.3 Transmission spectrum mask and the maximum permitted power level of spurious emission or unwanted emission

Technical aspects of the planning and protection of the broadcasting service are based upon information contained in Recommendation ITU-R BT.1368 (for digital systems) and Recommendation ITU-R BT.470 (for analogue systems). Further details are contained in the Australian Communications and Media Authority's (ACMA) *Broadcasting Services (Technical Planning) Guidelines 2007*[1]. These guidelines are supplemented by more detailed information contained in the ACMA *DTTB Planning Handbook*[2]. A summary of differences between the Australian digital terrestrial television service planning assumptions and the data contained in Recommendation ITU-R BT.1368 are as follows.

Australian planning for both analogue and digital terrestrial television is based on an assumption of fixed reception using outdoor receiving antennas. Therefore protection ratios relevant to Ricean channels are used where available. The DVB-T mode 64-QAM with 2/3 FEC and a 1/8 guard interval has been adopted as the basis for digital television planning, however to achieve a higher picture quality for SD/HD simulcast, a number of broadcasters have selected 64-QAM with 3/4 FEC and a 1/16 guard interval.

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[1] Refer http://www.acma.gov.au/WEB/STANDARD/pc=PC_90249.

[2] Refer http://www.acma.gov.au/WEB/STANDARD/pc=PC_91853.

Protection ratios for digital-digital and digital-analogue co-channel and adjacent channel interference from other television broadcasting services were first defined in July 1999. Only minor changes have been made to those original values. The values used in Australian planning are the same as the 64-QAM, 2/3 FEC values set out in Recommendation ITU-R BT.1368-7[3].

Australia's planning for digital television services takes into account a legislated requirement that "... in SDTV digital mode in that area should achieve the same level of coverage and potential reception quality as is achieved by the transmission of that service in analogue mode in the same area". Following this approach, Australia's digital services are typically planned with a maximum e.r.p. of 6 dB less than same band analogue television services.

The operating radiated power levels of digital services across the VHF and UHF bands are chosen on the basis of addressing the coverage requirements of each transmitter. Radiated power levels of particular digital services in band III range up to 50 kW e.r.p. in metropolitan areas and up to 100 kW e.r.p. in some regional areas. Services in band IV have been planned with e.r.p. levels that range up to 500 kW e.r.p. and services in band V range up to 1.25 MW e.r.p. in regional areas.

Australian digital television planning is based on provision of a minimum median field strength level. The Australian planning values are reasonably close to the values that can be derived from the sample calculation value provided in Table 44 of Recommendation ITU-R BT.1368-7[4].

The Australian values are higher than values that would be derived from the Recommendation. The difference is due to: inclusion of a 1 dB higher receiver noise figure allowance; use of 6.7 MHz rather than 7.6 MHz for the receiver bandwidth; and use of frequencies at the top rather than the middle of each band as the reference frequency for the calculation. The Australian minimum field-strength calculations also include a 1 dB "Interference margin" for the support of co-channel, frequency reuse planning.

Planning guidelines in Australia also specify minimum median field strengths (referred to a measurement height of 10 m above local terrain) for digital television services as shown in Table 1[5, 6].

TABLE 1

Minimum median field strength for DTTB Planning in Australia

Environment	Band III (dB(μV/m))	Band IV (dB(μV/m))	Band V (dB(μV/m))
Urban	66	71	74
Suburban	57	63	67
Rural	44	50	54

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3 The original 1999 values were adopted following protection ratio measurements made in 1998 using the "traditional" wanted-to-wanted protection ratio measurement approach, rather than the more recent *C*/(*I*+*N*) approach that appeared in Recommendation ITU-R BT.1368-1 (and later revisions).

4 Australian planning is based on provision of a service at 80% of locations within 200 m by 200 m areas. A 4.5 dB correction factor is applied to convert from a 50% of locations to an 80% locations field strength value.

5 Refer http://www.acma.gov.au/WEB/STANDARD/pc=PC_91853.

6 Field strength values used here apply to 7 MHz channel bandwidths.

To minimize the "cliff-effect", digital television services are planned to achieve the required protection ratio for better than 99% of the time, irrespective of whether the interference is considered to be continuous or tropospheric in nature.

The relevant protection ratios are not to be exceeded for more than 1% of the time. That is, the $E(50,1)$ value is used for the interfering field strength.

Spectrum masks for cases where a transmitter for digital terrestrial television is co-located with, and operating on a channel adjacent to:

a) a transmitter for analogue television are given in Fig. 3 and Table 2 for analogue television system B/PAL/A2;

b) a transmitter for digital television are given in Fig. 4 and Table 3 for COFDM digital television with a modulation mode of 64-QAM with an FEC of 2/3.

The masks shown in Figs 3 and 4 cover the minimum protection needed for analogue and digital television where the analogue and the digital television transmitters are co-located and are applicable for cases where:

– no polarization discrimination between digital and analogue television is used.

The masks are to be used for the comparison of e.r.p$_s$ of the wanted and unwanted services. Such comparison may be provided from calculation from the actual transmitter spectrum output and antenna system gains.

The masks provide the limit to the power and the out-of-band products of the unwanted digital service. The mask levels are fixed in relationship to the wanted service, hence the actual mask of the interfering service must be derived from the actual operating power of the interfering service and its relationship to the wanted analogue or digital service.

FIGURE 3

Spectrum mask for a digital terrestrial television transmitter operating with a co-located lower or upper adjacent channel analogue television transmitter

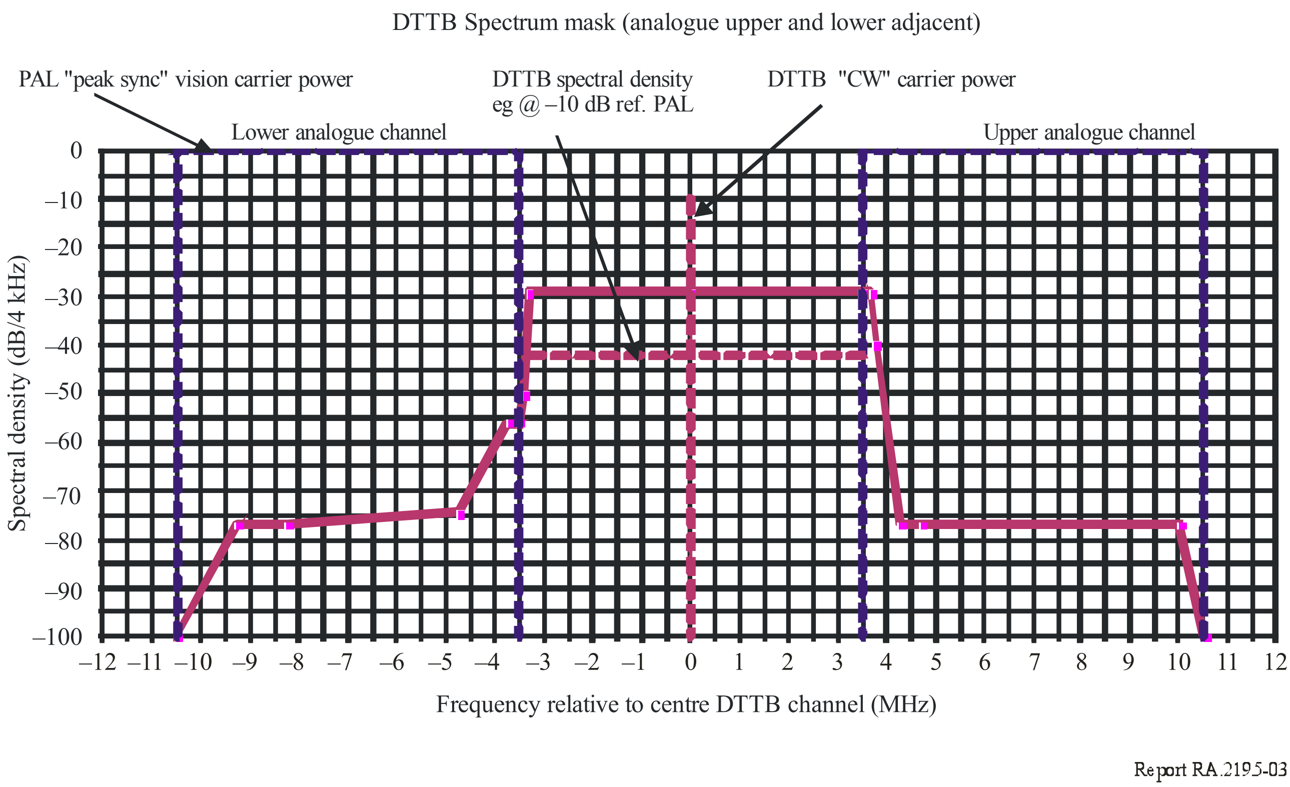

TABLE 2

Breakpoints for spectrum mask for a digital terrestrial television transmitter operating with a co-located lower or upper adjacent channel analogue television transmitter

Lower breakpoints										
Relative frequency (MHz)	–0	–3.3	–3.4	–3.5	–3.51	–3.75	–4.75	–8.25	–9.25	–10.5
Relative level (dB/4 kHz)	–29	–29	–50	–56	–56	–56	–74.5	–77	–77	–100

Upper breakpoints								
Relative frequency (MHz)	0	3.5	3.7	3.8	4.2	4.75	10	10.5
Relative level (dB/4 kHz)	–29	–29	–29	–40	–77	–77	–77	–100

FIGURE 4

Spectrum mask for a digital terrestrial television transmitter operating with a co-located lower or upper adjacent channel digital terrestrial television transmitter

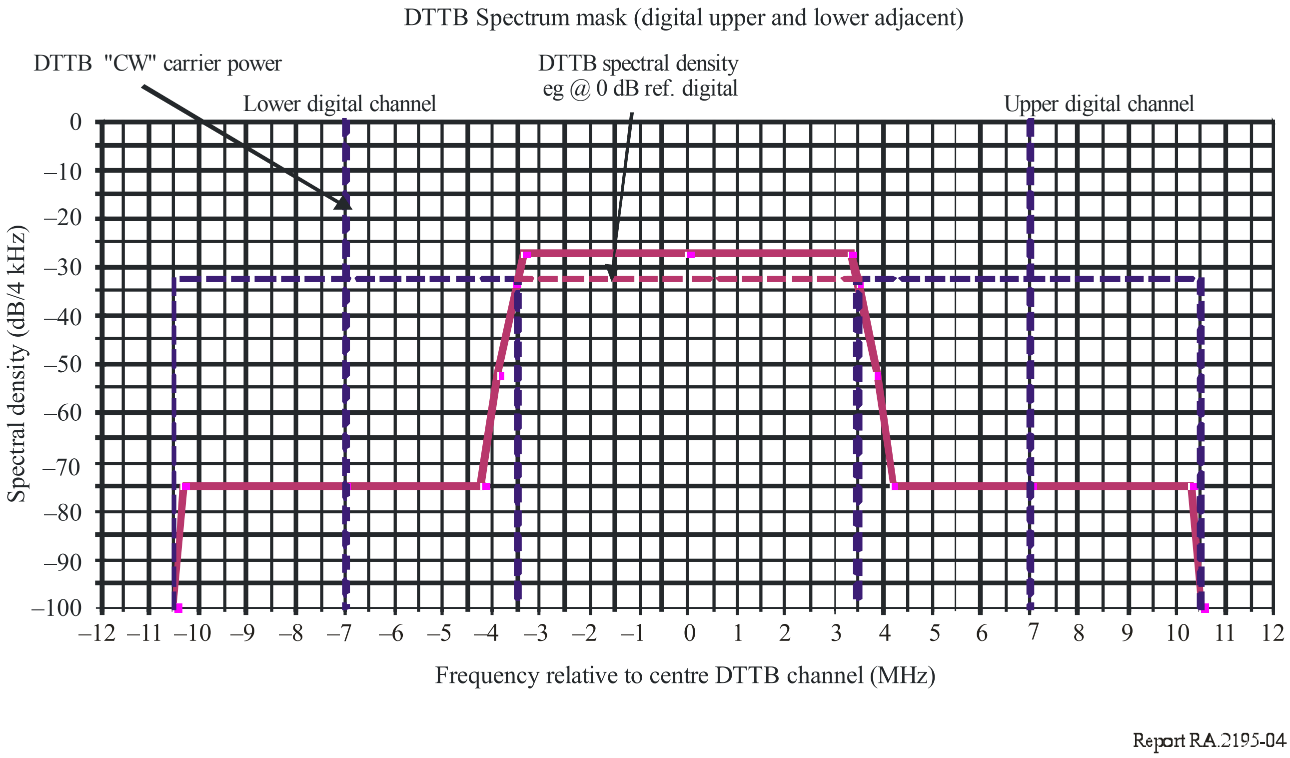

TABLE 3

Breakpoints for spectrum mask for a digital terrestrial television transmitter operating with a co-located lower or upper adjacent channel digital terrestrial television transmitter

Breakpoints								
Relative frequency (±MHz)	0	3.35	3.5	3.85	4.2	7	10.3	10.5
Relative level (dB/4 kHz)	–27	–27	–33	–52	–75	–75	–75	–100

1.4 Radio astronomy observations in frequency bands allocated to terrestrial broadcasting

As noted in § 1.2, digital television in Australia has been planned for operation within the frequency bands 174-230 MHz and 526-820 MHz. There are no Australian allocations to radio astronomy in these bands and therefore radio telescopes are sited in less populated areas to minimize the risk of interference from various radiocommunication systems including broadcasting.

The Parkes radio telescope currently observes in the band 700-764 MHz on a no protection from interference basis.

The Australian SKA Pathfinder (ASKAP) telescope, planned for operation from 2013, will have an operating frequency range of 700 to 1 800 MHz. Furthermore, Australia is a potential site for the Square Kilometre Array (SKA), which is expected to have an operating frequency range from 100 MHz to 25.25 GHz.

2 Brazil[7]

2.1 Brazilian DTT standard

The Brazilian Digital Terrestrial Television (DTT) standard is an adapted version of the Japanese ISDB-T standard, and it is called SBTVD-T. At the most recent meetings of Working Party 6A and Radiocommunication Study Group 6, on May 7 and 8, the Brazilian DTT standard was accepted to be included as additional normative reference to System C of Recommendation ITU-R BT.1306. System C corresponds to the ISDB-T.

2.2 Date of transition

In Brazil, all terrestrial broadcasting television transmissions are being under simulcasting process, i.e. simultaneous transmission of the analogue standard (PAL-M) in one 6 MHz channel (VHF and UHF bands), and its digital pair (SBTVD-T) in another 6 MHz channel (UHF band only). The switch-off of all analogue terrestrial broadcasting television transmission systems is scheduled on 29 June 2016.

[7] The Brazilian DTT standard (SBTVD-T) is published by the Brazilian Technical Standards Association (ABNT) and can be freely downloaded from the following link: http://www.forumsbtvd.org.br/materias.asp?id=112.

2.3 Frequency allocations and assignments

In Brazil, each TV channel is 6 MHz wide prior to and after the digital transition. The frequency range covers the VHF slots (channels 2-4 in 54-72 MHz band; channels 5-6 in 76-87.8 MHz band; channels 7-13 in 174-216 MHz band), and the UHF slot (channels 14-69 in 470-806 MHz band). After the transition, all DTT transmissions will be only in the UHF slot.

2.4 Current situation of digital terrestrial television deployment in Brazil

Digital terrestrial television (DTT) was officially launched in the city of São Paulo, SP, on 2 December 2007. Two years after its introduction, DTT coverage has already reached 19 markets, which are served by 40 stations, reaching almost 56 millions of inhabitants. All stations provide one-seg service for portable devices. Some stations broadcast high-definition programming during part of the day.

Table 4 presents the current availability of DTT with the correspondent market.

TABLE 4

Situation of DTT deployment in Brazil as of 2009

Market (city, state)	Population reached (in thousands)	Number of stations
São Paulo, SP	16 930	10
Rio de Janeiro, RJ	9 113	5
Belo Horizonte, MG	5 032	4
Fortaleza, CE	3 000	2
Salvador, BA	2 948	1
Recife, PE	2 623	1
Brasília, DF	2 557	3
Curitiba, PR	2 459	1
Porto Alegre, RS	2 185	1
Goiânia, GO	1 760	2
Vitória, ES	1 648	2
Campinas, SP	1 600	1
Teresina, PI	794	1
Campo Grande, MS	747	1
Uberlândia, MG	622	1
Cuiabá, MT	545	1
Santos, SP	418	1
São José do Rio Preto, SP	414	1
Florianópolis, SC	402	1
Total	55 797 (29% of country’s population)	40

3 Japan[8]

3.1 Date of transition

In Japan, all terrestrial broadcast television transmissions are being switched over from the analogue standard (NTSC-M as per Recommendation ITU-R BT.1701) to the digital one (System C as per Recommendation ITU-R BT.1306 or ISDB-T). The analogue terrestrial broadcasting television transmission systems are scheduled to be stopped on 24 July 2011.

3.2 Frequency allocations and assignments

In Japan, each TV channel is 6 MHz wide prior to and after the digital transition. The frequency range covers the "VHF" (channels 1-12; 90-108 MHz and 170-222 MHz) band and the "UHF" (channels 13-62; 470-770 MHz) band prior to the transition, and only the "UHF" (channels 13-52; 470-710 MHz) band after the transition. The centre frequency of the transmitted signal is shifted upward by 1/7 MHz (142 857 Hz) from the centre frequency of each channel.

Table 5 shows the UHF channels and the ISDB-T programme-signal centre frequencies in Japan, and Fig. 5 shows the transmission spectrum configuration corresponding to a single ISDB-T channel. Segment No. 0 must be positioned at the centre of the entire band, with successively numbered segments placed alternately above and below that segment.

TABLE 5

UHF channels and ISDB-T programme-signal centre frequencies

UHF channel number	Channel 13	Channel 14	....	Channel 52
Centre frequency	473 + 1/7 MHz = 473.142857 MHz	479 + 1/7 MHz = 479.142857 MHz	....	707 + 1/7 MHz = 707.142857 MHz

After the transition, channels 1-12 in the VHF band and channels 53-62 in the UHF band will no longer be used for regular analogue TV broadcasting. Reallocation plan for the "vacated frequency range" has already been made for the broadcasting and mobile services.

3.3 Transmission spectrum mask and the maximum permitted power level of spurious emission or unwanted emission[9]

The transmission-spectrum limit mask is specified as shown in Fig. 6. The related break points for the spectrum mask are listed in Table 6. The maximum permitted power level of spurious emission or unwanted emission is shown in Table 6.

[8] Technical characteristic of the terrestrial digital television broadcasting in Japan was taken from the Association of Radio Industries and Businesses (ARIB) STD-B31 Version 1.6 at http://www.arib.or.jp/english/html/overview/doc/6-STD-B31v1_6-E2.pdf. It should be noted that this version is now under revision, and revised information has been incorporated in this contribution.

[9] The above specifications are accompanied with transitional measures (supplementary provisions to the Radio Equipment Rules – Ministerial Ordinance No. 119 issued by the MIC (Ministry of Internal affairs and Communications) in 2005).

FIGURE 5

OFDM-segment numbers on the transmission spectrum

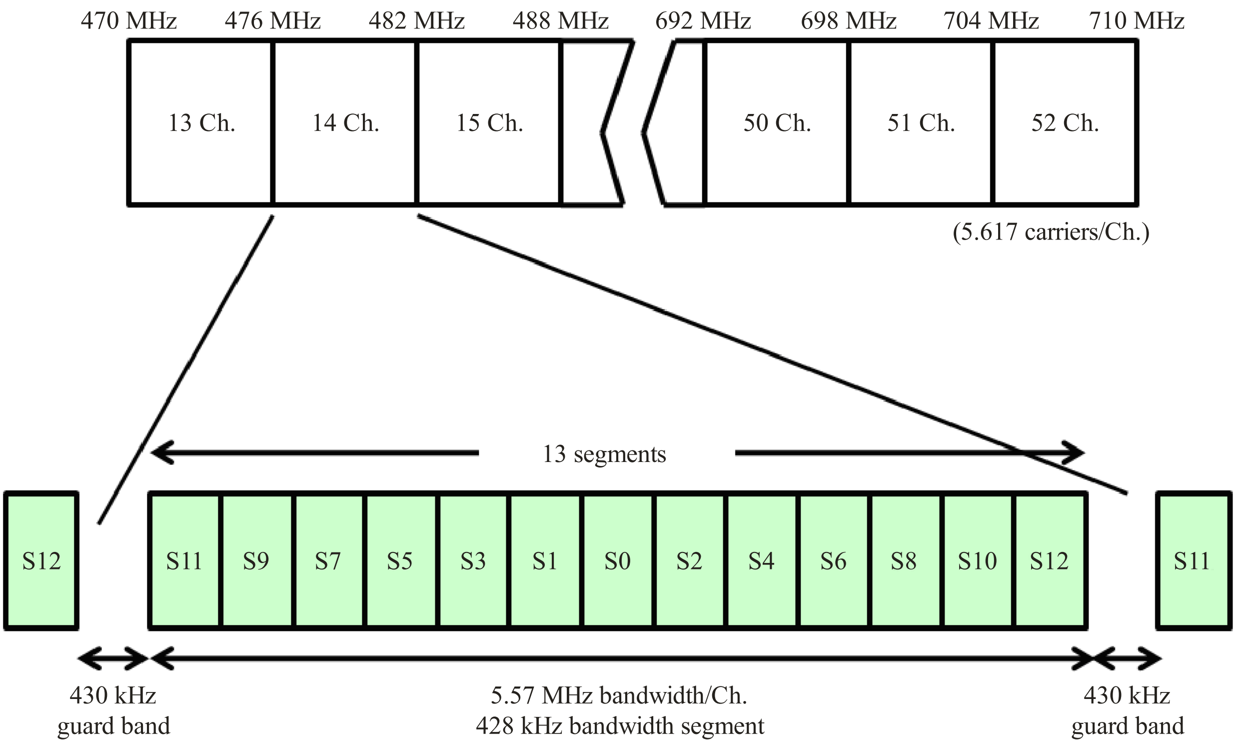

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FIGURE 6

Transmission-spectrum limit mask for digital terrestrial television broadcasting

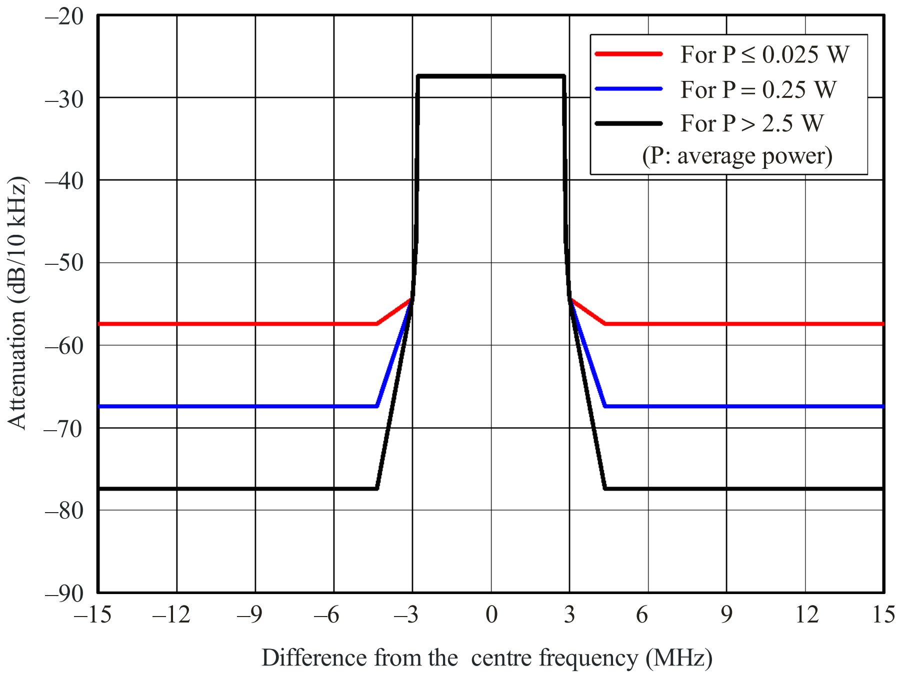

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TABLE 6

Breakpoints for transmission-spectrum mask

Difference from the centre frequency (MHz)	Attenuation relative to average power *P* (dB/10 kHz)	Type of stipulation
±2.79	–27.4	Upper limit
±2.86	–47.4	
±3.00	–54.4	
±4.36	–77.4(1), (2)	

(1) If the frequency corresponding to an adjacent channel number (the channel number between 13 and 62 that is one number different from the channel number of the television broadcasting corresponding to the allocated frequency in the Plan for the Available Frequencies Allocated to Broadcasting stipulated in Item (ii) of § (2) of Article 7 of the Japanese Radio Law) is not used for standard television broadcasting (excluding digital broadcasting and restricted to the effective radiation power that is less than ten times the own effective radiation power) within the own broadcasting area, the following specifications should be applied:

–(73.4 + 10 log P) dB/10 kHz in the case of radio equipment whose transmission power is more than 0.25 W and equal to or less than 2.5 W;

–67.4 dB/10 kHz in the case of radio equipment (except for the case (2)) whose transmission power is 0.25 W or less.

(2) If the frequency corresponding to an adjacent channel number is not used for standard television broadcasting (excluding digital broadcasting) within the own broadcasting area, the following specifications should be applied:

–(73.4 + 10 log P) dB/10 kHz in the case of radio equipment whose transmission power is more than 0.025 W and less than 0.25 W;

–57.4 dB/10 kHz in the case of radio equipment whose transmission power is 0.025 W or less.

NOTE 1 – For the adjacent channels of radio equipment that amplifies multiple waves together, an attenuation of –27.4 dB/10 kHz relative to average power *P* can be set as the upper limit regardless of the Table 6.

TABLE 7

Maximum permitted power level of spurious emission or unwanted emission

The power supplied to antenna transmission line	Maximum permitted power level of spurious emission in out-of-band domain	Maximum permitted power level of unwanted emission in spurious domain
Above 25 W	20 mW or less and 60 dB(1) lower than the average power of basic frequency	12 mW or less and 60 dB lower than the average power of basic frequency
Above 1 W and 25 W or less	25 μW or less	25 μW or less
1W or less	100 μW or less	

(1) For the maximum permitted power level of spurious emission in the out-of-band region for transmission equipment whose transmission power exceeds 8 kW, the values specified in Table 6 shall be used.

3.4 Radio astronomy station in the frequency range between 470 and 710 MHz

There is only one radio astronomy station (Hiraiso) which has a receiver covering from 500 to 2 500 MHz. However, in Japan, there is no allocated band for the radio astronomy service in the frequency range between 470 and 710 MHz. Therefore the Hiraiso station could observe the band between 470 and 710 MHz in accordance with RR No. 4.4.

4 United States of America

4.1 Date of transition

In the United States of America, all full-service broadcast television transmissions transitioned from the National Television System Committee (NTSC) analogue standard to the Advanced Television Systems Committee (ATSC) digital standard on or before 12 June 2009[10, 11]. The date was originally set as 17 February 2009, but at the last minute was delayed by Congress until 12 June 2009 to allow more time for the public to prepare[12].

4.2 Changes to frequency allocations

In the United States, each TV channel is 6 MHz wide, both prior to and after the digital transition. Most TV users in the United States of America are familiar with two informal band designations: "VHF" (channels 2-13)[13] and "UHF" (pre-transition channels 14-69; post-transition channels 14-51). Figures 7 and 8 show the broadcast television spectrum in the United States of America before and after the digital transition, respectively. The figures include the frequency extent and the corresponding redshift for the 1 420 MHz spectral line of hydrogen, z(HI), for each channel.

As part of the transition, 18 television channels (52-69) totalling 108 MHz of spectrum (698-806 MHz) will no longer be used for regular TV broadcasting. This range has been reallocated on a primary basis to fixed and mobile services, and will be used for next-generation wireless systems; forward-link-only video broadcasting directly to wireless handsets; and public safety communication systems.

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[10] Digital Television Transition and Public Safety Act of 2005, Title III of Public Law 109-171, Deficit Reduction Act of 2005, (8 February 2006), http://www.gpo.gov/fdsys/pkg/PLAW-109publ171/content-detail.html.

[11] Some television transmissions, notably low-power stations, and television translators and boosters that provide "fill-in" service to communities lacking sufficient signal coverage, are allowed to continue to transmit analogue signals. Although no timetable is presently set for a mandated transition to digital for these stations, market forces will mandate their eventual switch-over.

[12] DTV Delay Act, Public Law 111-4, (11 February 2009), http://www.gpo.gov/fdsys/pkg/PLAW-111publ4/content-detail.html.

[13] For reasons involving the relocation of the early FM broadcast band, TV Channel 1, which used to occupy 44-50 MHz, was never used for regular TV service and was reallocated to non-broadcast use in 1948.

FIGURE 7

U.S. television channels before the digital TV transition

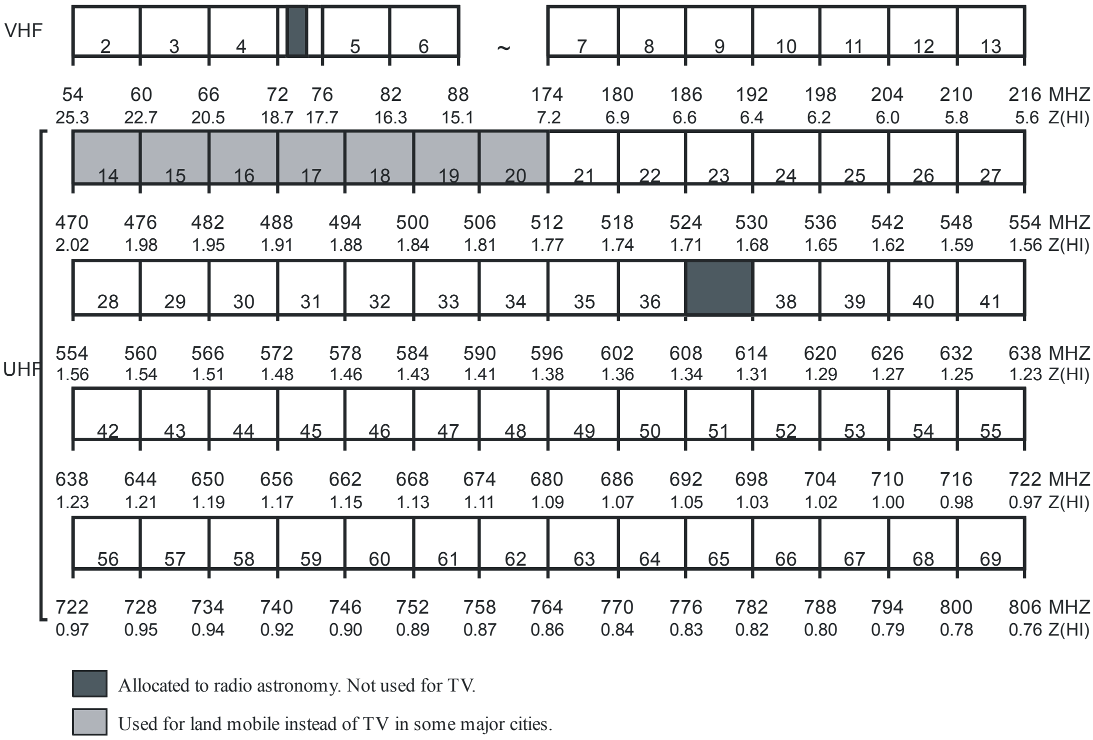

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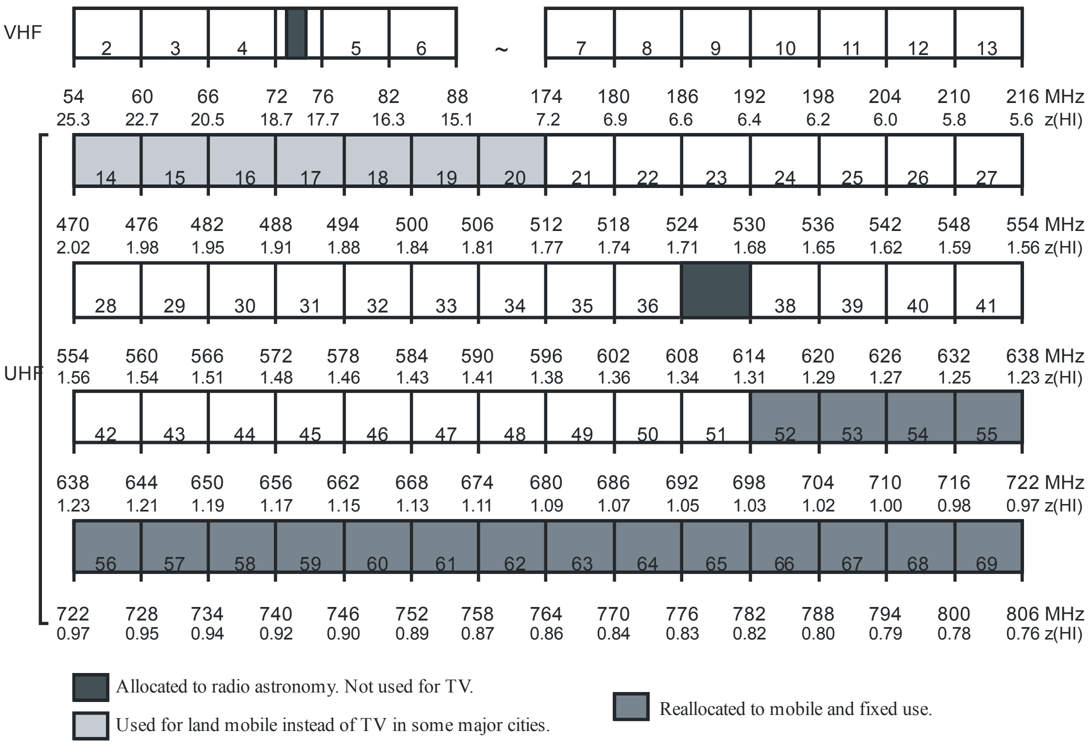
FIGURE 8

U.S. television channels after the digital TV transition



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Both prior to and after the digital transition, TV channel 37 (608-614 MHz) is allocated to the radio astronomy service on a primary basis instead of to broadcasting, and it is shared with low-power medical telemetry and medical telecommand devices operating in the same band. Such devices must not cause interference to the radio astronomy service, and when used within 80 km of the Arecibo telescope, the Very Large Array, or the Green Bank Telescope, or within 32 km of any VLBA station, must be pre-coordinated with the radio astronomy service through the U.S. National Science Foundation[14].

4.3 Changes to allotments and assignments

To manage interference among TV stations, the U.S. Federal Communications Commission (FCC) maintains a table of allotments that specifies which channels may be used in each market area. Specifically, the allotment table specifies the channel, geographic coordinates, maximum effective radiated power, maximum antenna height above average terrain (HAAT), and antenna radiation pattern. The allotment table is based upon complex considerations of signal requirements specified in the transmission standard, the regional propagation environment, assumed receiver performance characteristics, market size and population, allotments and allocations in bordering countries, and other relevant factors.

Adding complexity as far as predicting impacts to a specific radio astronomy station, television licensees may petition the FCC to alter the existing allotment table, and may have the allotments changed if, in the judgment of the FCC, good cause is shown and the change is technically feasible. Such petitions may be submitted (and possibly granted) at any time, even years or decades after the initial table is created.

The initial post-transition DTV table of allotments was issued by the FCC in August 2007[15] Compared to the analogue TV table of allotments, significantly fewer DTV stations will occupy the lower VHF band (channels 2-6; 54-88 MHz non-contiguous) compared to before the transition. Figures 9 and 10 compare the number of allotted stations per channel before and after the transition, respectively. Overall, this improves the possibility of using the range 54-72 MHz and 76-88 MHz for unprotected radio astronomy observations, although this depends specifically on the proximity of stations on channels 2-6 to a given radio astronomy station.

Within a year of the publication of the post-transition allotment table, dozens of petitions to modify the table have been submitted. Radio astronomers should monitor the petitions for possible conflicts with nearby observatories.

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[14] Section 95.1119 of Title 47 of the U.S. Code of Federal Regulations.

[15] FCC 07-138, seventh Report and order and eighth further notice of proposed rule making in the matter of advanced television systems and their impact upon the existing television broadcast service (Media Bureau Docket No. 87-268), 6 August 2007.

FIGURE 9

Number of analogue TV stations per channel in the United States of America before the DTV transition

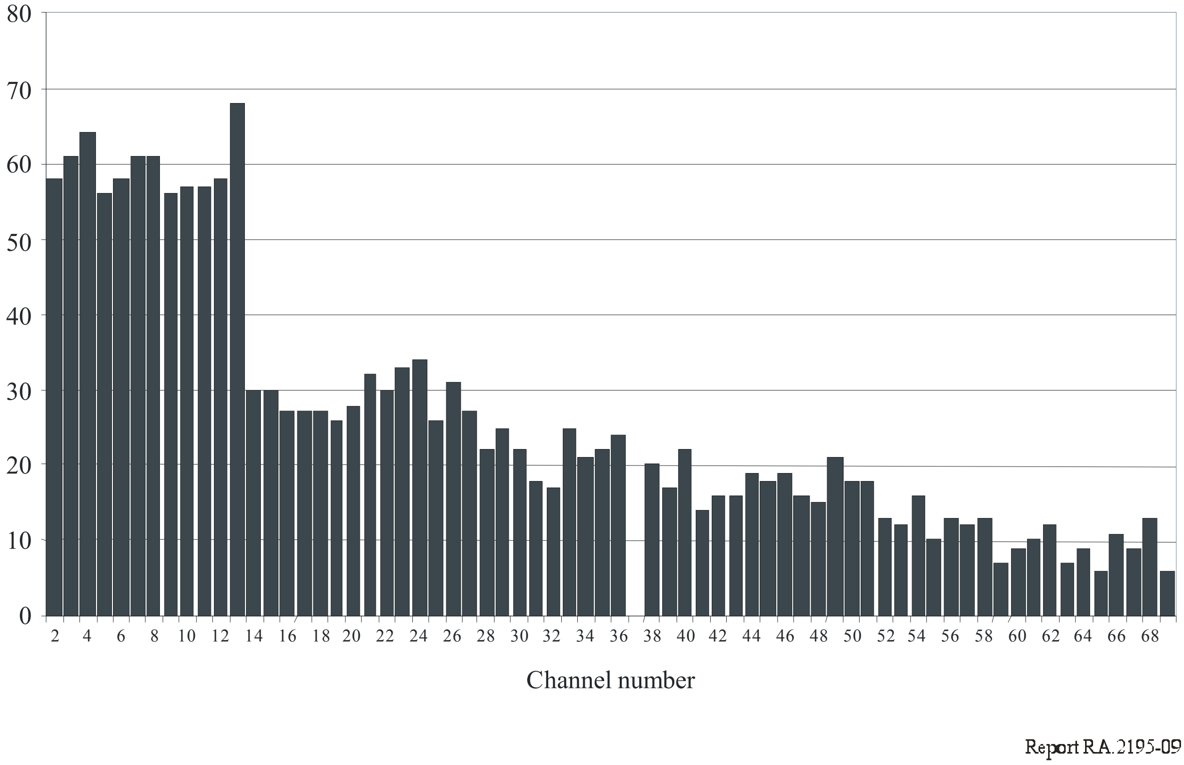
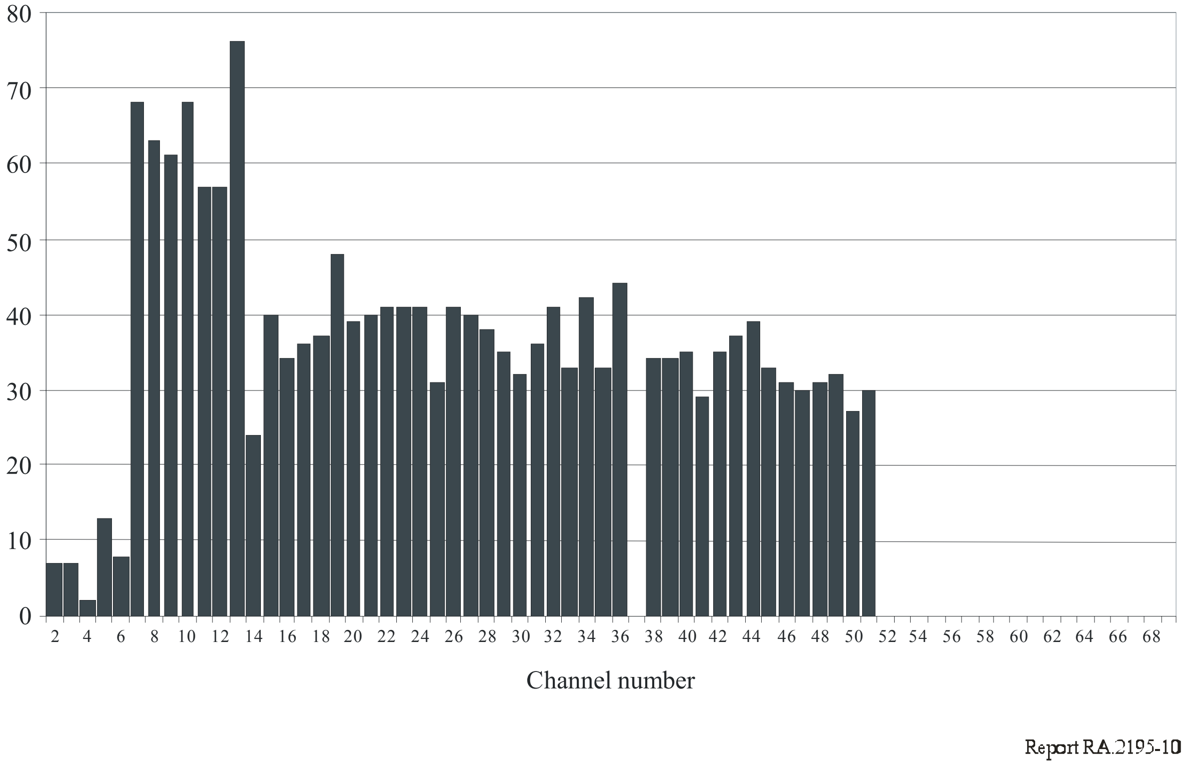


FIGURE 10

Number of digital TV stations per channel in the United States of America after the DTV transition



4.4 Changes to allowed transmit power and unwanted emissions

Because digital TV transmission standards include error correction for handling mild interference and noise situations, and equalization algorithms and comb filters for handling multipath interference; and because digital television sets take advantage of improvements in modern receiver design and performance, the total transmit power required for digital TV systems is somewhat less than that required for previous analogue TV coverage. As a result, the maximum allowable effective isotropic radiated power (e.i.r.p.) established in the FCC's rules for digital TV is less than that allowed for analogue TV. Table 8 is a simplification of the analogue and digital e.i.r.p. limits. Specific limits depend upon the transmit antenna's HAAT and possibly other factors[16].

TABLE 8

Maximum allowed power for broadcast television

Channel range	Frequency (MHz)	Maximum e.i.r.p. (kW)	
		Analogue	Digital
2-6	54-72 and 76-88	164	74
7-13	174-216	518	262
14-69 (14-51 digital)	470-806 (470-698 digital)	8 222	1 640

Limits on unwanted emissions from analogue television stations are only loosely defined in the FCC rules:

> "Spurious emissions, including radio frequency harmonics, shall be maintained at as low a level as the state of the art permits. As measured at the output terminals of the transmitter (including harmonic filters, if required) all emissions removed in frequency in excess of 3 MHz above or below the respective channel edge shall be attenuated no less than 60 dB below the visual transmitted power … In the event of interference caused to any service greater attenuation will be required[17]."

Because the rule does not specify a measurement bandwidth, it is impossible to translate the limit into a power spectral density. Also, there is no specification on limits for out-of-band emissions or any unwanted emissions less than 3 MHz from the channel edge. Since the visual carrier e.i.r.p. (if assumed to be 75% of the total signal power) can be as much as 6×10^6 W, then spurious emissions could be as much as 6 W e.i.r.p., assuming identical antenna gain for the spurious emissions and the visual carrier.

Limits on unwanted emissions from digital television stations are better defined[18]. Within the first 500 kHz outside a channel edge, unwanted emissions must be attenuated at least 47 dB below the average transmitted power within the authorized channel. More than 500 kHz but less than 6 MHz from the channel edge, unwanted emissions must be attenuated by an amount at least:

$$-11.5(\Delta f + 3.6) \qquad \text{dB}$$

[16] See § 73.61 (analogue power limits) and § 73.622 (digital power limits) of Title 47 of the U.S. Code of Federal Regulations.

[17] Section 73.687(e) of Title 47 of the U.S. Code of Federal Regulations.

[18] Section 73.622(h) of Title 47 of the U.S. Code of Federal Regulations.

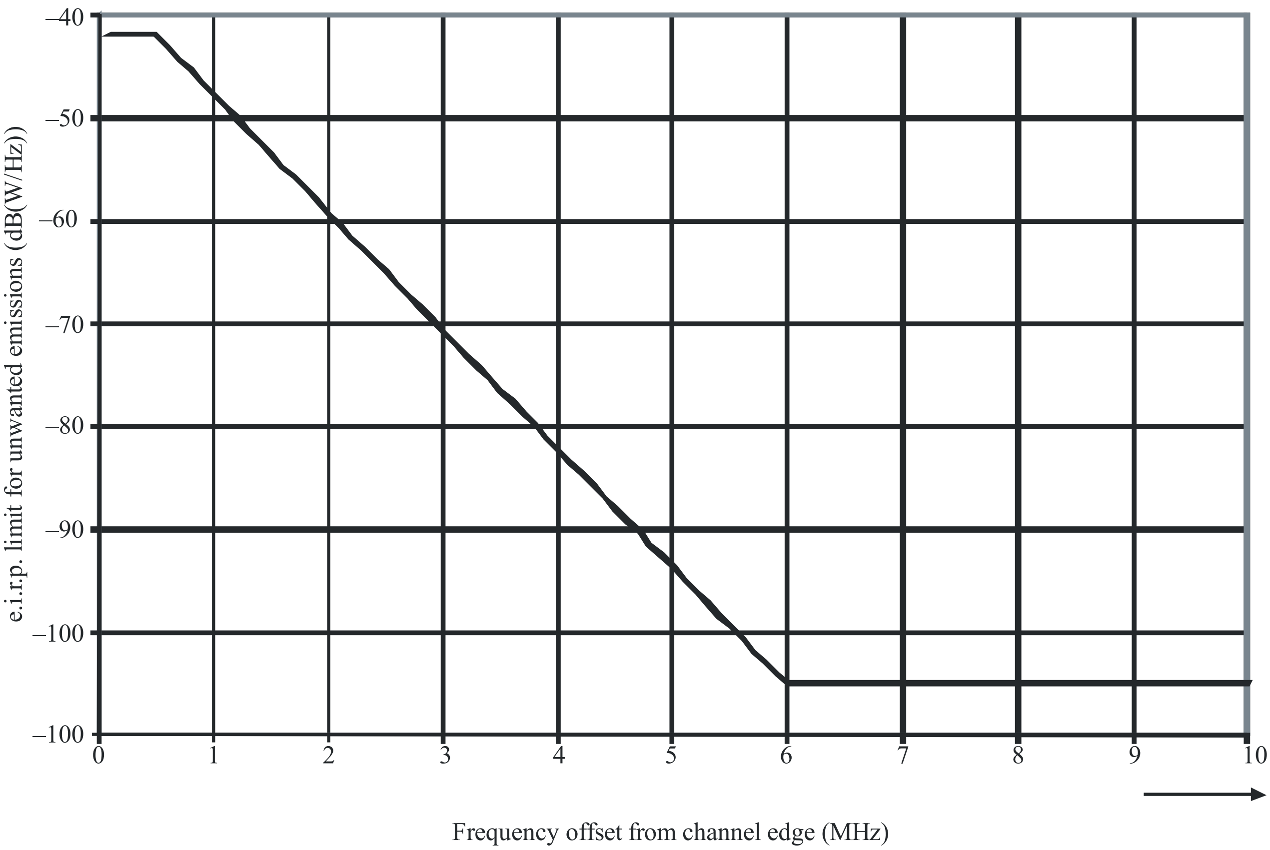
where:

Δf is the frequency offset in MHz.

Beyond 6 MHz, the attenuation must be at least 110 dB. All measurements are referenced to a bandwidth of 500 kHz. The measurements are to be made at the transmitter output port; however, assuming that the transmission cable/waveguide structure and antenna are no more efficient for out-of-band and spurious emissions than they are for in-band emissions, the e.i.r.p. of the unwanted emissions relative to the desired emissions will be attenuated in dB at least as much as the specification. Figure 11 shows the unwanted emission limits for a maximum-power (1 640 kW) DTV station, with the limits converted into dB(W/Hz).

FIGURE 11

Out-of-band emissions limits for full-power (1 640 W e.i.r.p.) digital TV station



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4.5 Changes to the spectrum of the transmitted signal

The analogue NTSC standard results in a transmitted signal whose power is strongly concentrated in the carriers of three separate signals:

Video signal

The luminance information is transmitted in an amplitude-modulated vestigial sideband signal. The carrier frequency is 1.25 MHz above the lower channel boundary, and the higher frequency components of the lower sideband are strongly attenuated to meet out-of-band emission limits.

Chrominance signal

The two differences between the relative amplitudes of the three primary colours are sent as the amplitude and phase of the chrominance signal, which is centred at 4.5 × (455/572) MHz (approximately 3.5795 MHz) above the video carrier (approximately 4.8295 MHz above the lower channel boundary).

Audio signal

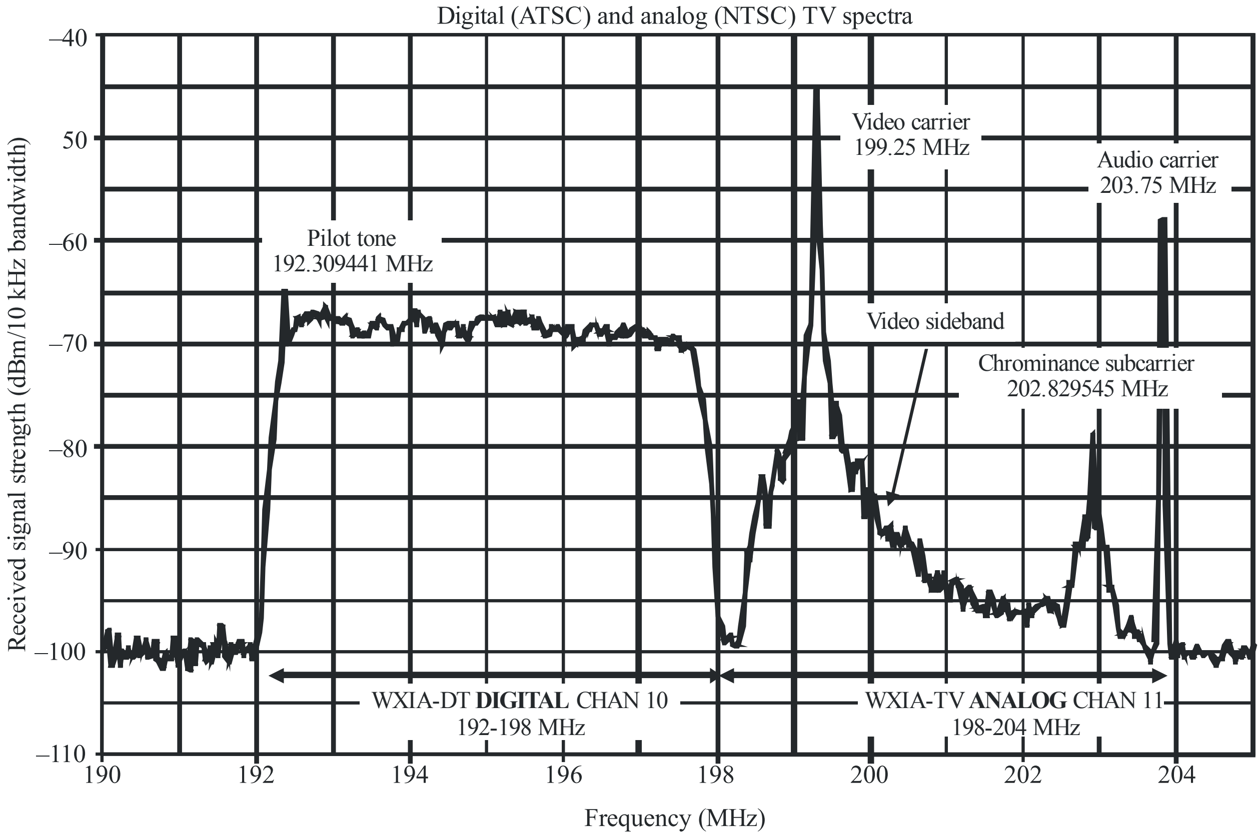
The audio is sent as a wideband FM signal centred 5.75 MHz above the lower channel boundary.

The digital ATSC standard[19] calls for an 8-level Vestigial Sideband (8VSB) modulation scheme, which results in a generally flat and featureless spectrum across the central 4.76 MHz of the 6 MHz channel width.

The in-channel spectral roll-off follows a linear phase root raised cosine filter, with roll-off beginning 620 kHz from the channel edges and down 3 dB 310 kHz in from the channel edges. The full-width half-maximum bandwidth of the ATSC signals is 5.38 MHz. A narrow pilot tone is added 310 kHz above the lower channel boundary and is used by the receiver for frequency synchronization. The central 4.76 MHz of the ATSC spectrum is essentially flat and featureless.

FIGURE 12

Direct comparison of equivalent digital ATSC (left) and analogue (NTSC) TV spectra, transmitted by the same station from the same tower at the same time



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[19] Available at http://www.atsc.org/cms/index.php/standards. The RF/transmission system characteristics portion of the standard is contained in http://www.atsc.org/cms/standards/a53/a_53-Part-2-2007.pdf.

Figure 12 directly compares the analogue NTSC and corresponding digital ATSC signal transmitted from the same station on the same tower, using adjacent TV channels. Although the power of the digital signal is somewhat less than its analogue counterpart, the analogue signal is strongly concentrated in the carriers of the three components.

Unprotected use of TV spectrum by the radio astronomy service may rely on the lower power spectral density levels between NTSC signal components to allow observations in-channel but between the NTSC component carriers, when there was a large separation between the radio astronomy station and the TV transmitter. Between the carriers, the power spectral density of the analogue signal is many dB less than the digital counterpart. Figure 13 shows the linear ratio of the power spectral density of the digital signal in Fig. 12 to the power spectral density of its analogue counterpart in the same figure. Over more than 94% of the spectrum, the digital power spectral density exceeds that of the analogue signal by as much as a factor of 1 100 (> 30 dB). For this reason, it is anticipated that after the transition to DTV is complete, a given TV station's digital signal will create a greater challenge for opportunistic radio astronomy use of the band when compared to the station's analogue precursor. As an illustration, Fig. 14 compares the estimated separation required from analogue and digital TV signals to meet the levels of detrimental interference derived in Recommendation ITU-R RA.769.

FIGURE 13

Ratio of digital (ATSC) to analogue (NTSC) power spectral densities in Fig. 12

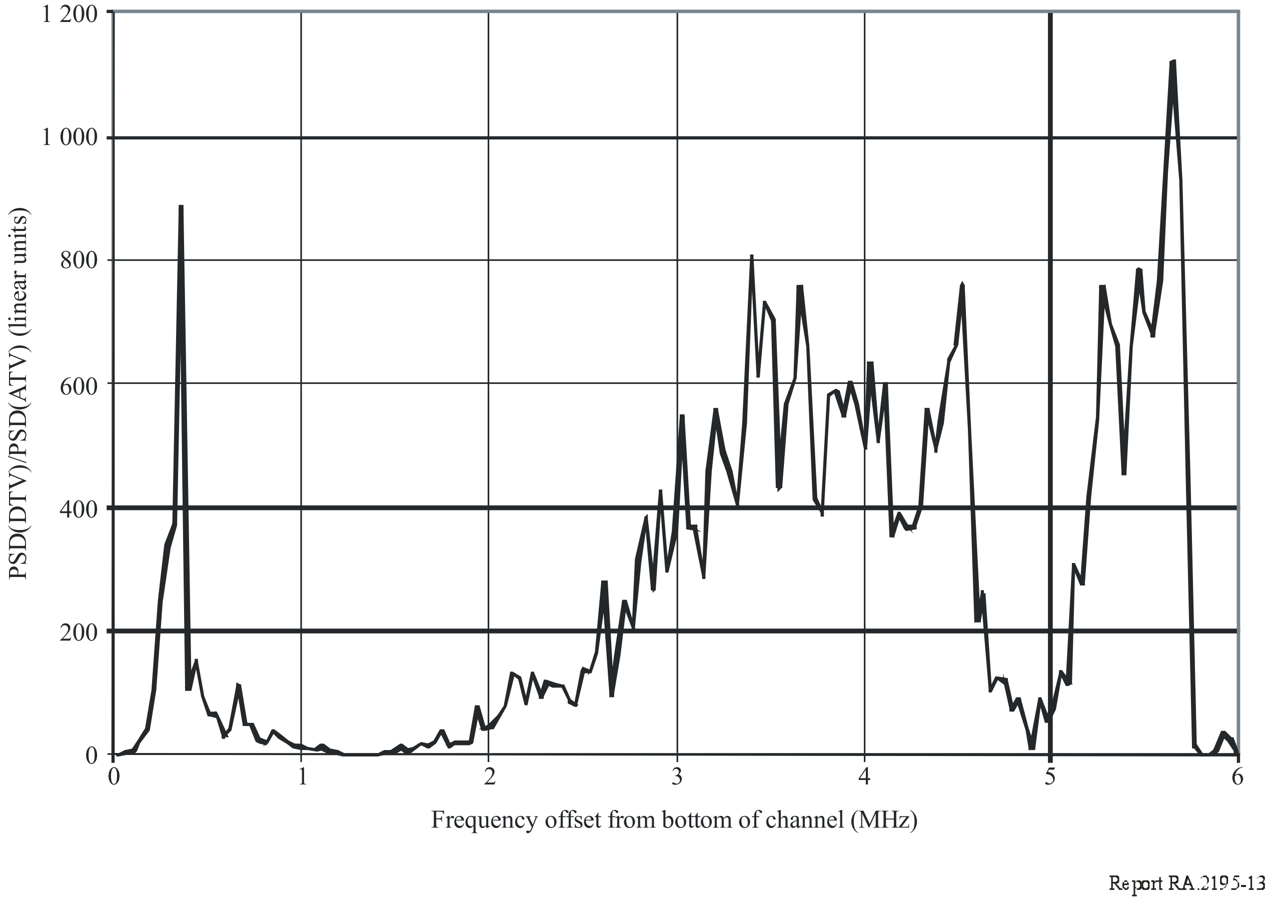
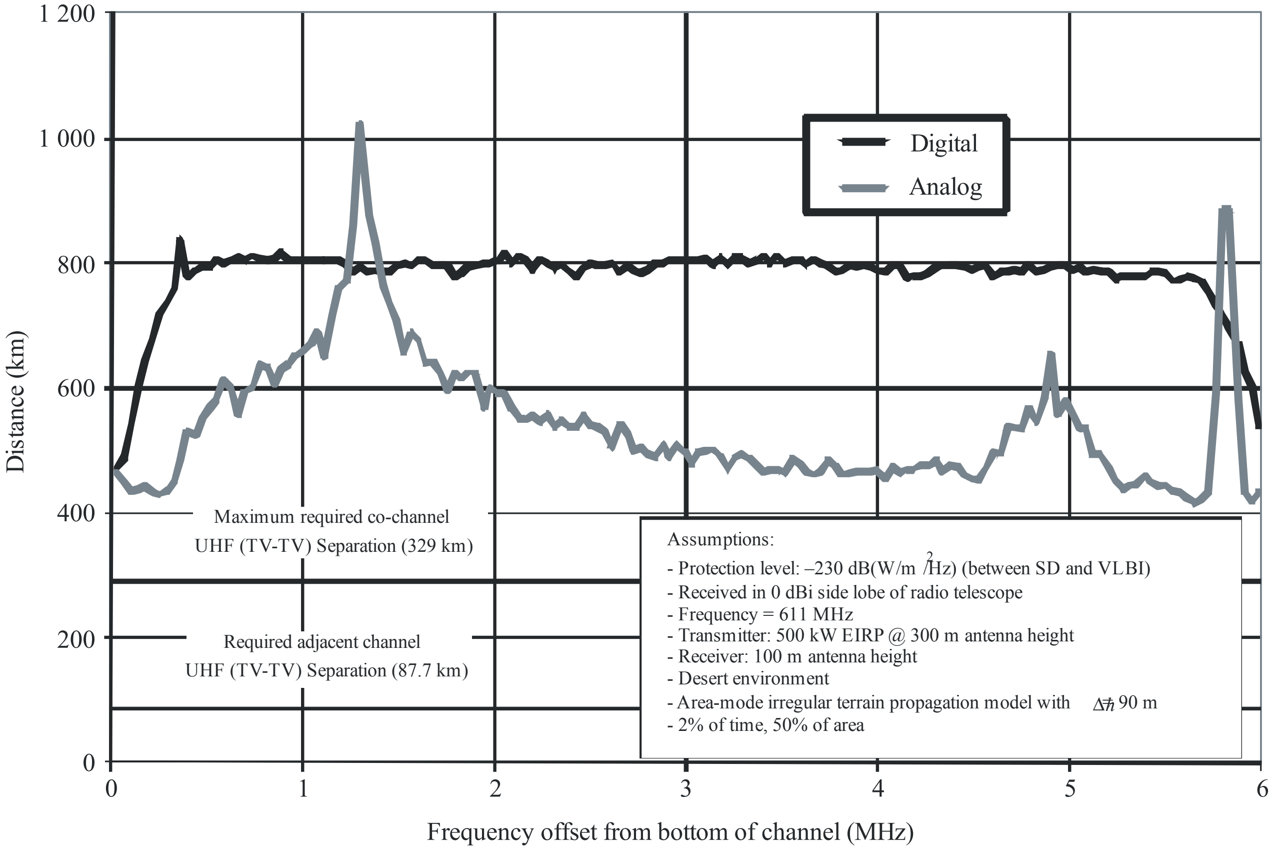


FIGURE 14

Minimum separation distance between digital and analogue TV stations to meet radio astronomy interference objectives under the given assumptions



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