Useful Information about TV (and DAB) RFI As Observed by HERA

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Purpose

The aim of this document is to present some information about television interference including official allocations, types of signals observed, and spectral behavior of those signals.

South Africa Allocation

The general allocation of TV in the HERA observing band is in the 2019 final frequency migration plan, on page 88 of the document (90 of the uploaded pdf) - shown in the panels below. The TV allocation essentially runs from 174-254 MHz, omitting 238-246 MHz. T-DAB (Terrestrial Digital Audio Broadcasting) is allocated from 214 to 230 MHz, which is gleanable from a separate document referred to in the right-hand most column of the charts shown here (specifically Government Gazette (GG) #36321).

Frequency Band (MHz)	Existing Allocation in NRFP 2018 (Applications)	Proposed Allocation/ (Utilization)	Notes on migration/ usage
	Non-specific SRDs (173.2375 – 173.2875 MHz) Wireless microphones and assistive listening devices (173.7 – 175.1 MHz))		
174 - 223	BROADCASTING Television Broadcasting T-DAB	Radio Frequency Migration Plan Government Gazette Number. 36334 (Notice No. 352 & 353 of 2013)	Refer to Terrestrial Broadcasting Frequency Plan Government Gazette Number 36321 (Notice No. 298 of 2013) The Radio Frequency Spectrum Assignment Plans is to be optimised and additional T-DAB multiplexes developed on a national and regional basis. Also refer to the Digital Sound broadcasting discussion document published in Government Gazette, No. 41534 (Notice No 161 of 2018). (refer to 4.10.6)
223 – 230 & 230 - 238	BROADCASTING (Television Broadcasting) T-DAB	Radio Frequency Migration Plan Government Gazette Number. 36334 (Notice No. 352 & 353 of 2013)	Refer to Terrestrial Broadcasting Frequency Plan Government Gazette Number 36321 (Notice No. 298 of 2013)

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			The Radio Frequency Spectrum Assignment Plans is to be optimised and additional T-DAB multiplexes developed on a national and regional basis. Also refer to the Digital Sound broadcasting discussion document published in Government Gazette, No. 41534 (Notice No 161 of 2018). (refer to 4.10.6)
238 – 246 & 246 - 254	BROADCASTING (246 – 254) (Television Broadcasting) MOBILE (238 – 246) (238-242.95 MHz PMR and/or PAMR International Distress Frequency at 243 MHz (242.95 – 243.05 MHz) 243.05-246.00 MHz Low-power devices)	Radio Frequency Migration Plan Government Gazette Number. 36334 (Notice No. 352 & 353 of 2013)	Refer to Terrestrial Broadcasting Frequency Plan Government Gazette Number 36321 (Notice No. 298 of 2013) Radio Frequency Spectrum Assignment Plan to be developed for VHF Digital Television.
335.4 - 380	FIXED NF6 (FWA (336 – 346 MHz) FWA (356 – 366 MHz) 366-380 MHz (Govt.) Digital Trunking (Emergency) 335.4-336 MHz PMR and/or PAMR)	Radio Frequency Migration Plan Government Gazette Number. 36334 (Notice No. 352 & 353 of 2013)	Migrate existing fixed links to above 3 GHz as per SADC proposed common sub-allocation/ utilization (refer to 4.10.10)

Signal Types

From reading the frequency migration plan, it is indicated that as of mid-2019, the analog TV shutoff is not complete in South Africa. This means there are still stations in South Africa that are broadcasting analog TV signals, and it turns out these signals share an allocation with the digital TV signals (namely the bands in the chart above). The charts below are taken from GG #36321 (this is actually a *2013* document), page 34-35 (38 of the uploaded pdf). They show the specific allocations for each broadcast TV channel. Each channel is given 8 MHz over which to do its business. Analog TV spans the whole range from 174-238 MHz, and then another channel exists from 246-254 MHz. Digital TV runs from 174-214 MHz in the 2013 document. The 2019 document indicates that there are plans for DTV to show up everywhere there is analog TV currently. Evidence in SSINS (shown at the end) shows that some of this migration past 214 has already occurred. As mentioned above, DAB runs from approximately 214-230 MHz. The analog TV signals are in PAL-I format (Phase Alternating Line, System I, like eye). More information about this will be included in the "spectrum characteristics" section. The analog TV signals possess visual, audio, and chrominance carrier wave components. The visual carrier is listed in the chart below. The audio carrier is always 6 MHz higher than the corresponding visual carrier, which is stated on page 13 (17 in the uploaded pdf) of GG #36321. I could not find mention of the chrominance carrier, but there is a known PAL-I standard.

Table 4: Channel numbering in band III (174 – 238MHz and 246 – 254MHz) currently allocated for Analogue Television Broadcasts

Channel No.	Channel Limits (MHz)	Vision Carrier Frequency (MHz)
4	174 – 182	175.25
5	182 – 190	183.25
6	190 – 198	191.25
7	198 – 206	199.25
8	206 – 214	207.25
9	214 – 222	215.25
10	222 – 230	223.25
11	230 – 238	231.25
13	246 – 254	247.13[5]

Table 5: Channel numbering in band III (174 – 214MHz) allocated for Digital Television Broadcasts

Channel No.	Channel Limits (MHz)
5	174 – 182
6	182 – 190
7	190 – 198
8	198 – 206
9	206 – 214

Table 6: Channel numbering in band III (216 – 230MHz) Digital Audio Broadcasts

Channel No.	Assigned Frequency (MHz)	Frequency Block Bandwidth (MHz)	Lower Guard band (kHz)	Upper Guard band (kHz)
11a	216.926	216.160-217.696	320	176
11b	218.640	217.872-219.408	176	176
11c	220.352	219.584-221.120	176	176
11d	222.064	221.296-222.832	176	336
12a	223.936	223.168-224.704	336	176
12b	225.648	224.880-226.416	176	176
12c	227.360	226.592-228.128	176	176
12d	229.072	228.304-229.840	176	-

Spectrum Characteristics

The two types of digital signal (DVB and DAB) have very blocky power spectral densities (PSD). Theoretical PSD are shown below from the European Telecommunications Standards Institute (ETSI). The documents detailing the technical standards of these signals have been uploaded to the shared HERA drive, and are also available by searching on etsi.org. The DVB signals are 8 MHz wide, while the DAB signals are 1.536 MHz wide (not including the shoulders below -30 dB).

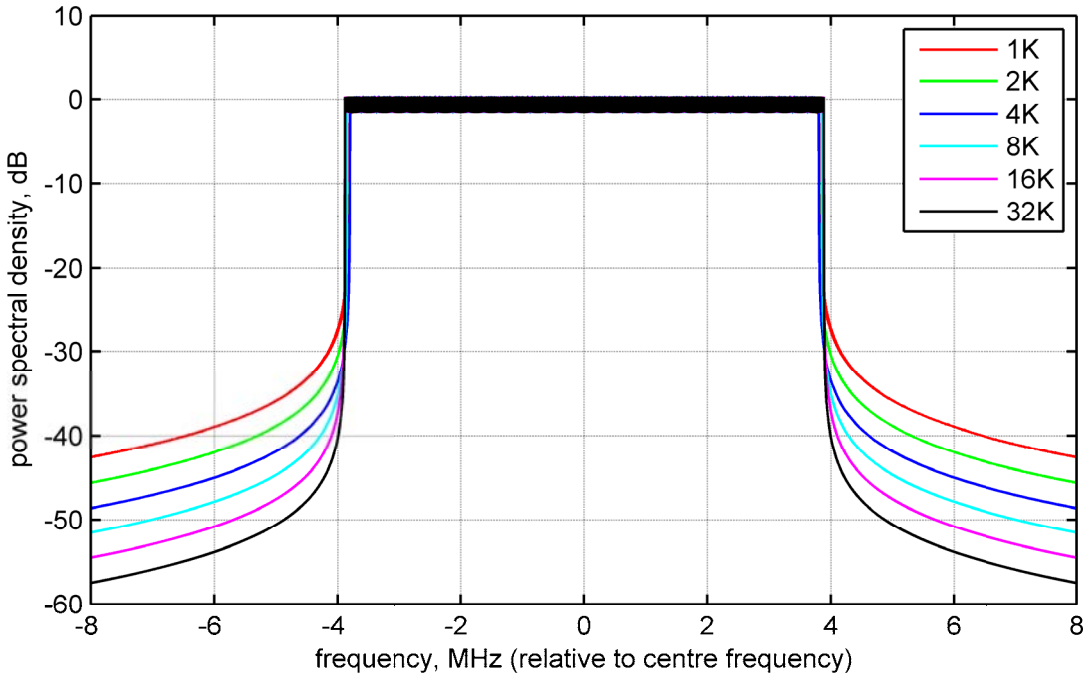


Figure 54(a): Theoretical DVB-T2 signal spectrum for guard interval fraction 1/8 (for 8 MHz channels and with extended carrier mode for 8K, 16K and 32K)

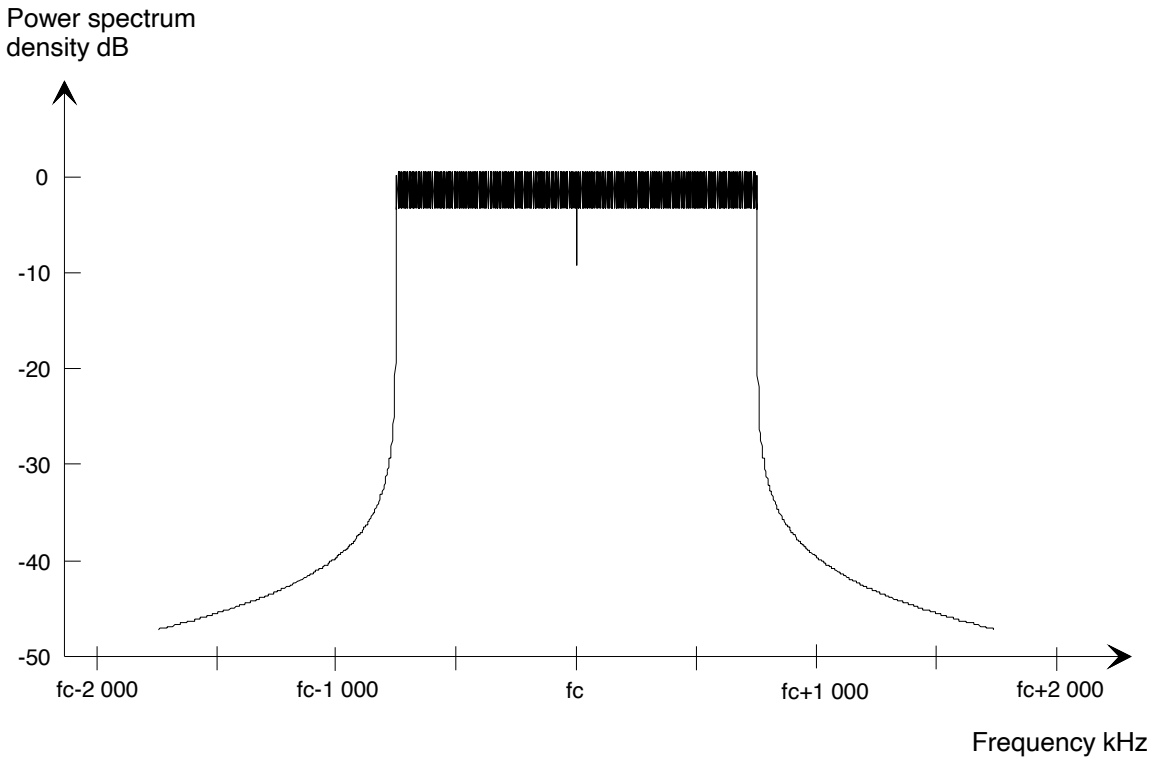
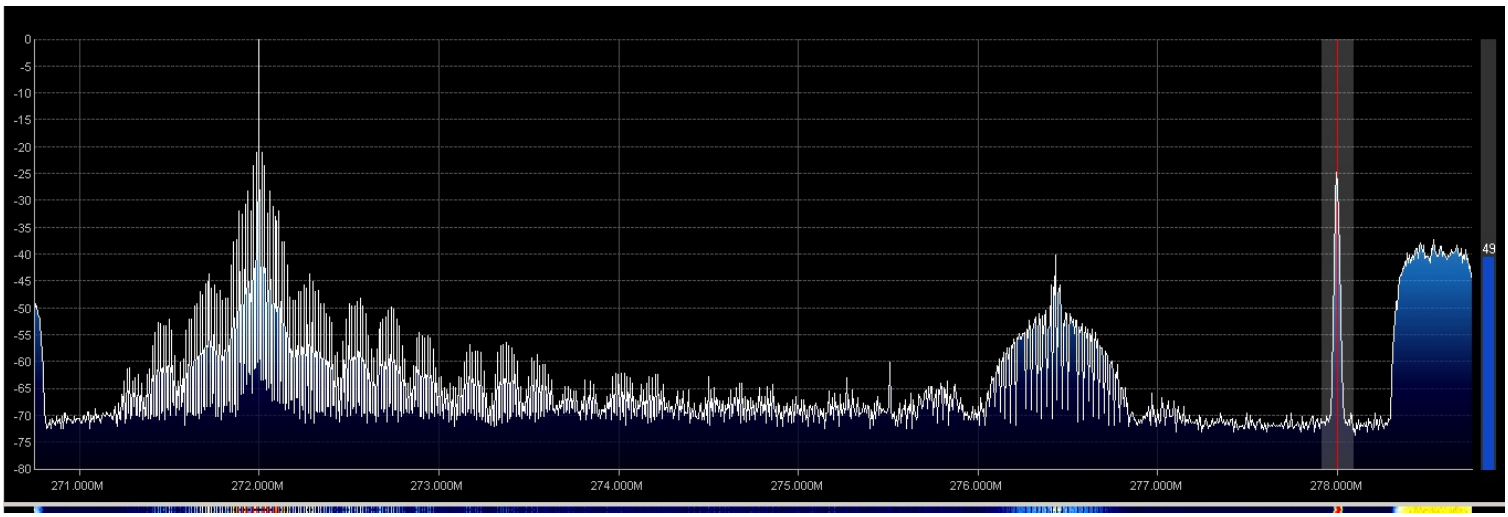
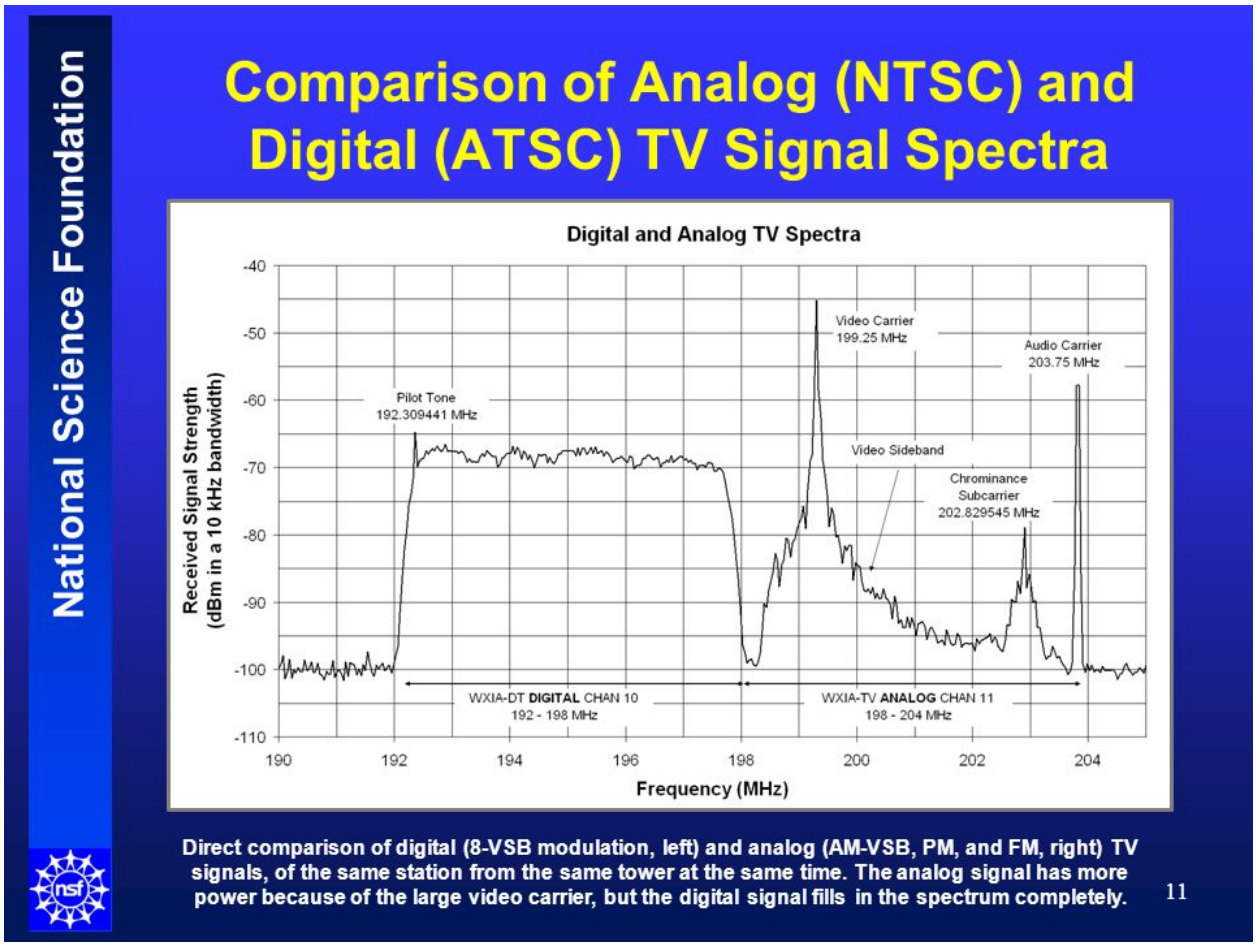


Figure 88: Theoretical DAB transmission signal spectrum for transmission mode I

The analog TV signals are slightly more complicated in terms of frequency structure. As mentioned earlier, the are made up of three main carrier waves: visual (luminance), audio, and chrominance. An example of a measured PAL-I signal is shown below. This picture came from wikipedia. The signals are meant to occupy 8 MHz of bandwidth. Wikipedia suggests that in the PAL-I broadcast, the visual/audio separation is always meant to be 6 MHz, and the visual/chrominance separation is meant to be (approximately) 4.434 MHz. This is distinctly different from a digital TV broadcast, which has flat power over the allocated range and then a sharp rolloff. We also show a slide on the next page from a talk by Andrew Clegg in 2010, at the U.S. National Science Foundation Third Summer School on Spectrum Management for Radio Astronomy, titled *Digital TV and its impact on Radio Astronomy*. This slide compares a digital and analog TV signal side-by-side.



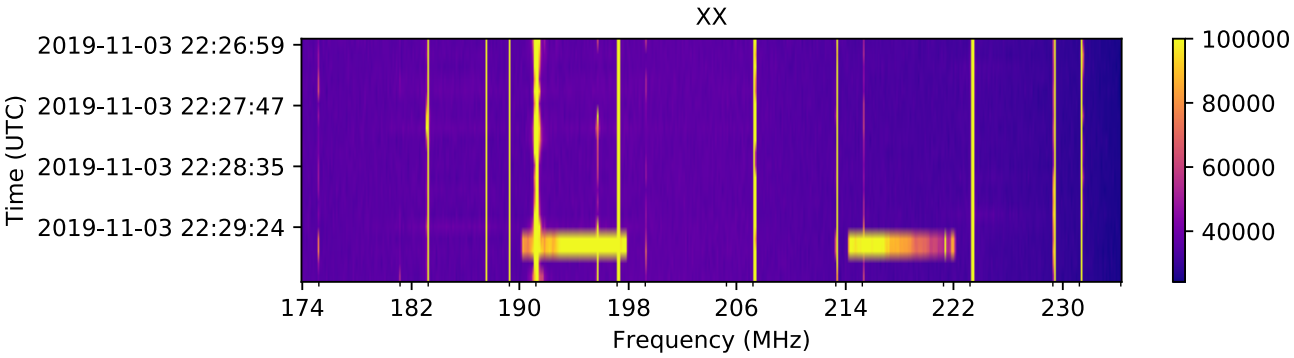


Here we can see an NTSC analog TV transmission next to an ATSC digital TV transmission. This is slightly different than the PAL-I format. Notably, it is only 6 Mhz wide, and so the carrier spacings are slightly different. However, there are important qualitative features - namely that the power in the analog signals tends to be strongly concentrated around the carrier waves. The power is used much more evenly in the digital signal. This is not to say that data between the carrier wave peaks is necessarily usable, or that analog TV is favorable to digital TV. Both are very bad for EoR science. This suggests that if analog TV is observed by HERA for a given time, that the entire 8 MHz allocation be flagged at that time. In the next section we show some SSINS plots of H3C data.

HERA's SSINS

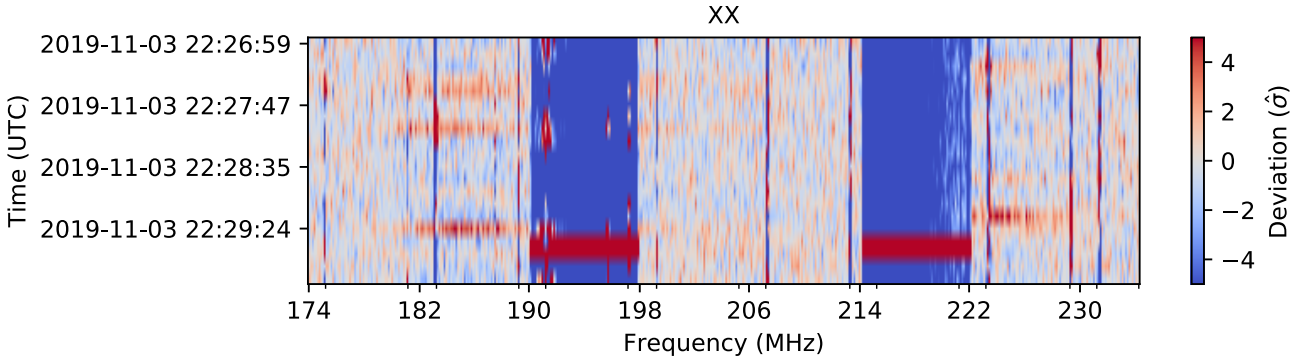
On the next page we show some SSINS for 3.5 minutes of H3C data. The major ticks are the channel edges listed from the tables above. The minor ticks are the visual and audio carrier frequencies. We can see that we are observing a mixture of analog and digital television, sometimes simultaneously. In fact, in all H3C SSINS I've looked at (about 3.5 hours, single night), the analog carriers are visible in most of the allocated channels we observe for the duration of the observation, suggesting that all data above 174 Mhz is contaminated by analog television for these hours. Observations from H1C

suggest that this is a common occurrence, and not isolated to a particularly bad night of observing.



The later part of the observation in XX shows evidence of digital TV contamination, namely the blocky chunks occupying 190-198 MHz and 214-222 MHz. There is also very good alignment between relatively narrow interference events and the carrier frequencies of analog TV signals. The width of the visual carrier seems to vary a little with time, perhaps due to some change in amplitude raising the shoulders of the residual carrier signal.

In order to tease out fainter events, we time-average the top plot and subtract it from each data point. We then normalize so that it is in z-score units. This is shown below. We can see that there are possibly even fainter observations of digital TV from 182-190 MHz, shown as the faded red blocks in the middle of the obs.



Altogether, we see that the data above 174 MHz is quite strongly and frequently contaminated. Its usability will need to be assessed. Outlook doesn't look great.