DM smearing for MeerKAT

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Fast radio bursts (FRB) have observed pulse widths ranging from ∼1 to 10 msec. In most cases, the intrinsic pulse is unresolved, and the observed pulse widths are dominated by inter-channel DM smearing or interstellar scattering. The former can be mitigated by using a larger number of frequency channels at the cost of greater processing or storage requirements. The latter effect is strongly frequency-dependent and can not be corrected for.

The interchannel DM smearing in microseconds is given by

$$\Delta \mathrm{t_{DM}} = 8.3 \mu \mathrm{s}\, \mathrm{DM} \left(\frac{\delta \nu_{\mathrm{MHz}}}{\nu^3_{\mathrm{GHz}}} \right) \tag{1}$$

where DM is the dispersion measure, $\delta\nu^2_{\mathrm{MHz}}$ bandwidth over which you want to calculate the smearing, and ν^{-3}_{GHz} is the observing frequency. Rearranging the terms and redefining in terms of the number of frequency channels N_ν and total bandwidth $\Delta\nu_{\mathrm{MHz}}$, i.e. $\Delta\nu_{\mathrm{MHz}} = N_\nu \delta\nu_{\mathrm{MHz}}$, we get

$$N_\nu = \mathrm{DM} \left(\frac{8.3 \mu s}{\Delta t_{\mathrm{DM}}} \right) \left(\frac{\Delta \nu_{\mathrm{MHz}}}{\nu^3_{\mathrm{GHz}}} \right) \tag{2}$$

To estimate the number of frequency channels, we have to make several assumptions:

- The amount of DM smearing we're willing to accept
- Total bandwidth - here I assume 875 MHz
- Observing frequency - here I have taken a range of 0.6 to 3.5 GHz. I don't know if there are any plans to do searches below ∼1 GHz. The number of channels at the low end gets ridiculous pretty quickly; ignore it if it's not applicable.
- Range of DMs for FRBs - here I assume 500 to 2500 pc cm^{-3}

Are 4k channels enough? The current provision for the wideband Feng from MeerKAT has 4k channels. Figure 1 shows a plot of the interchannel DM smearing as a function of frequency.

For the S-band receiver (1.7 to 3.5 GHz), the DM smearing is between ∼100 and 600 μsec. This is perfectly acceptable. For the L-band receiver (1 - 1.75 GHz), the DM smearing is ∼1 to 5 msec. This is slightly better than current FRB search backends. For comparison, the interchannel DM smearing for the HTRU-N (Effelsberg) and HTRU-S (Parkes) is ∼1

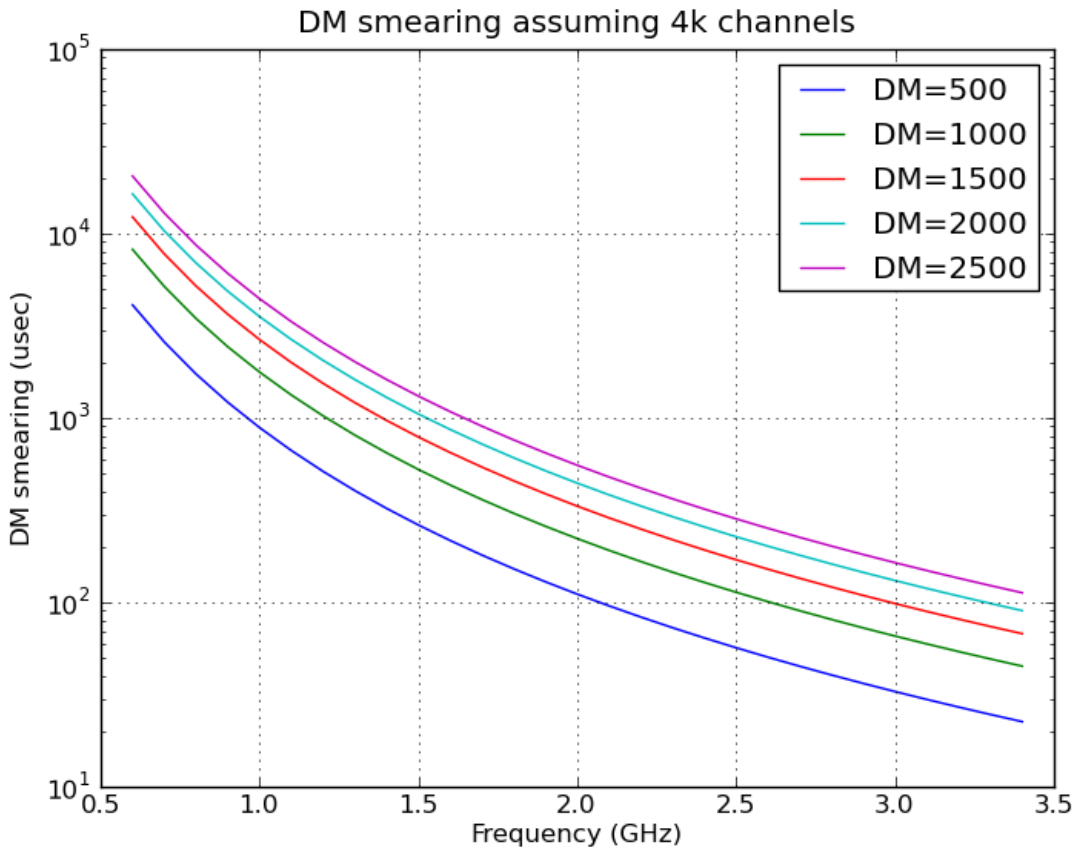

Figure 1: DM smearing in μsec over the MeerKAT observing frequencies assuming 4096 frequency channels for five DMs.

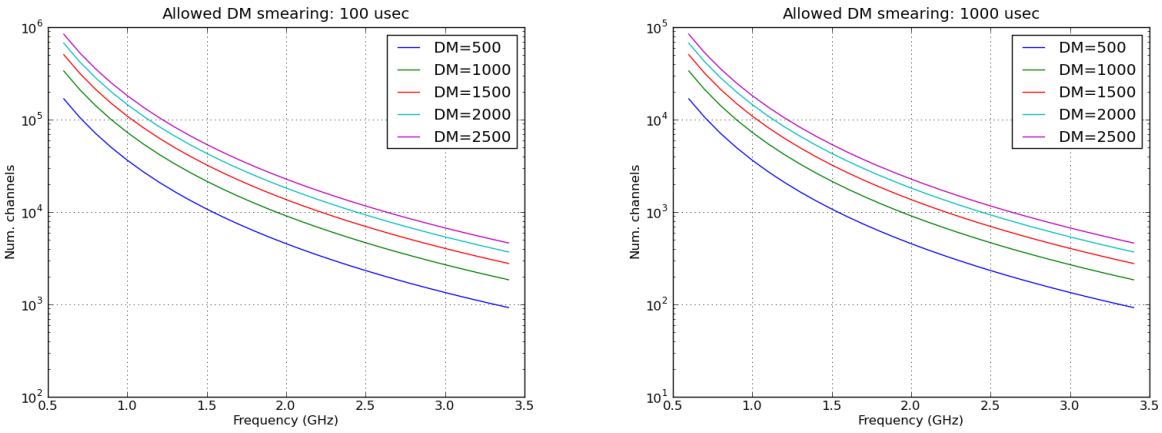

Figure 2: Number frequency channels needed to achieve the assumed minimum dispersion smearing times of 100 μs (left) and 1000 μs (right).

to 2 msec at the center of their bands for an FRB with DM=1000 pc cm^{-3}. In short, we'll be doing as well, but not much better than current instrumentation. We need to discuss in more detail whether this is good enough.

How many channels would we need to achieve a given minimum DM smearing? I've calculated the number of frequency channels needed to achieve a given, minimum DM smearing at a given observing frequency. Figure 2 shows the results for two values of $\Delta t_{\rm DM}$: 100 μs and 1000 μs.

A DM smearing time of $\sim$100 μs is comparable to the time resolution of the data, and is therefore roughly the number of channels needed to have no ill effects from DM smearing. For the purposes of FRB detection this is ideal but not strictly necessary. The value of $\sim$1000 μs represents the values typical for current pulsar backends on Effelsberg and Parkes and is also the lower limit to the observed pulse widths. (Although one should note that most FRBs aren't temporally resolved so the observed widths are dominated either by interchannel smearing or scattering.)

As stated above, the S-band receiver easily achieves this mark. At L-band, we would achieve this at the top of the band, and to reach this level at the bottom of the band, we'd need roughly 16k channels.