Presentation related to this report (or out there in Torun)

The DPFU parameter plays havoc with EVN calibration

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Summary:
Noting that the DPFU parameter is not necessary for proper calibration of the correlated flux density, and that its presence creates confusion, it is proposed to forgo its further use.
The simplest way to do this right away is to fix it at unity (DPFU = 1) in every rxg file of every station. This would mean expressing T_{cal} in units of Jansky and T_{sys} becoming F_{sys} or (almost) SEFD.

A few defining equations

The basic relationship between the amplitude of the correlation coefficient r_{obs} measured on a baseline involving two antennas to the antenna temperature T_A (in Kelvins) and the system temperature T_{sys} (K) is described by the equation:

$$r_{obs} = \frac{\rho}{b} = \sqrt{\frac{T_{A1}\,T_{A2}}{T_{sys1}\,T_{sys2}}}, \qquad (1)$$

where the b-factor is due to losses inherent in the row coefficient ρ arising because of crude recording and simplified correlation.

For mapping purposes it is important that the final correlation coefficient does not depend on the antenna elevation angle at stations. We might account for it by dividing the amplitude by the geometric mean of Poly(Elev) at the stations. The Poly is a correction coefficient, a polynomial in the elevation angle (or in the zenith distance) normalized (e.g. at the zenith, but any other elevation can serve the porpose) to unity, reflecting the loss of received flux due to changing atmospheric attenuation and telescope efficiency with the elevation.

$$r_{cor} = r_{obs} / \sqrt{\mathrm{Poly}_1\ \mathrm{Poly}_2} = \sqrt{\frac{(T_{A1}/\mathrm{Poly}_1)\ (T_{A2}/\mathrm{Poly}_2)}{T_{sys1}\ T_{sys2}}}, \qquad (2)$$

We see that such correction is equivalent to correcting the antenna temperatures which, however, we do not measure directly.

So obtained dimensionless quantity can be converted to the temperature scale (K):

$$r_{cor}/K = r_{cor} \sqrt{T_{sys1}\ T_{sys2}} = r_{obs} \sqrt{\frac{T_{sys1}\ T_{sys2}}{\mathrm{Poly}_1\ \mathrm{Poly}_2}} \qquad (3)$$

or the flux density scale in Janskys (Jy)

$$r_{Flux}/Jy = r_{obs} \sqrt{\mathrm{SEFD}_1\ \mathrm{SEFD}_2} = r_{obs} \sqrt{\frac{T_{sys1}}{\mathrm{DPFU}_1\ \mathrm{Poly}_1} \frac{T_{sys2}}{\mathrm{DPFU}_2\ \mathrm{Poly}_2}}, \qquad (4)$$

The **System Equivalent Flux Density**, SEFD = T_{sys} / (DPFU × Poly), of each telescope is a function of time calculated from our 'continuous' monitoring of the system temperature, and the DPFU factor, **Degrees Per Flux Unit** (K/Jy), is a constant representing the antenna gain at the elevation where Poly = 1.

Equation (4) is the one used in practice. It requires the use of three different quantities to correct the correlation coefficient. This document aims to reduce the number to two independent quantities. Namely, in terms of the equivalent flux density we would have:

$$r_{Flux} = r_{obs} \sqrt{\frac{F_{sys1}}{Poly_1} \frac{F_{sys2}}{Poly_2}}, \qquad (5)$$

where $F_{sys} = T_{sys}/DPFU$ is the total system noise power as measured by direct comparison with a nearby sky source (in this measurement the source flux density is not scaled by Poly), or with previously calibrated diode signal, F_{cal} (Poly-scaled). In any case, **to determine F_{sys} no knowledge of the DPFU is required**.

The above tells us that in principle we would satisfy the final users by providing the **F_{sys} or the total system noise power expressed in Janskys and the polynomial, Poly**.
Also, it seems there aren't good reasons why not to give the user the antabfs files filled just with the SEFD, i.e. F_{sys} already corrected with (divided by) the gain curve (Poly) evaluated at the proper elevation.

EVN practice

The present EVN calibration scheme may be summarized in the following steps (considerably simplified here for clarity):

Calibration experiments of CL... type

1) Using observations of a source of known flux density F_{so}, determine the **power of noise diode signal** in units of Jansky (Jy)

$$F_{cal} = F_{so} \times Poly \times (tpical - tpi)/(tponso - tpi), \quad (6)$$

where the quantities txxx are the signal power levels of the diode (tpical), background (tpi) and source (tponso), as measured by the Field System.

2) Convert this to the **noise temperature**:

$$T_{cal} = F_{cal} \times DPFU, \quad (7)$$

User experiments

3) Use this T_{cal} for 'continuous' monitoring of the **system noise temperature**:

$$T_{sys} = T_{cal} \times (tpi - tpzero) / (tpical - tpi'). \quad (8)$$

For the VLBA racks, the AGC gain level, tpgain, is used as proxy for tpi (tpi becoming a function of tpi', tpgain and tpgain'). So obtained T_{sys} data constitute the ANTAB files (along with DPFU and Poly).

4) Convert the **correlation coefficient** to the **correlated flux density** using the station determined T_{sys} of two stations (see Eq. (4) above):

$$r_{Flux} = r_{obs} \{ [T_{sys} / (DPFU \times Poly)]_1 \times \times [T_{sys} / (DPFU \times Poly)]_2 \}^{1/2}$$

or, same as Eq. (5) above,

$$r_{Flux} = r_{obs} \{ [F_{sys}/Poly]_1 \times [F_{sys}/Poly]_2 \}^{1/2} \quad (9)$$

or simply

$$r_{Flux} = r_{obs} \{ SEFD_1 \times SEFD_2 \}^{1/2} \quad (10)$$

Conclusion: The DPFU parameter is just a scaling factor not essential for the calibration process. It is being introduced at the beginning of the process (in T_{cal}) and is removed (from T_{sys}) at the end. Thus we are free to **ascribe virtually ANY nonzero value to it**, not affecting the correlated flux at all.

What do recent EVN station data tell us?

Here are actual DPFU in LCP and Poly values at L-band taken from pipelined N07L2 (and N06L1, for DPFU only). In the following table the antenna efficiencies in the two rightmost columns have been calculated as 2760×DPFU×Poly/(π×D^2/4), where the polynomial Poly has been evaluated for two extreme elevations, 0 (horizon) and 90° (zenith).

Station	DPFU (LCP) 2006	DPFU (LCP) 2007	Poly 0°	Poly 90°	D m	Efficiency 0°	Efficiency 90°
Cm	0.0047	0.0047	1.0	1.0	32	0.016	0.016
Ef	1.5516	1.55	1.0	1.0	100	0.545	0.545
Hh	0.0973	0.0954	0.9638	1.0	26	0.478	0.496
Jb	1.1849	1.1849	0.7373	0.9117	76	0.532	0.657
Mc	0.1080	0.1080	0.8869	0.9831	32	0.329	0.365
Nt	0.11	0.1102	1.0	0.9239	32	0.378	0.349
On	0.0800	0.0900	0.9099	0.9887	20	0.720	0.782
Sh	0.0653	0.0765	0.5009	0.4434	25	0.215	0.191
Tr	0.1400	0.1400	1.0	1.0	32	0.480	0.480
Ur	0.0880	0.0880	1.0	1.0	25	0.495	0.495
Wb*	1.0	1.0	1.0	1.0	14×25	0.402	0.402

*Tsys values for Wb are really SEFD of the array

Note on passing that at Nt and Sh the efficiency is higher at the horizon which may be indicative of their Poly being a function of the zenith distance rather then the elevation.

The table above shows that some efficiencies are clearly unrealistic (which implies unrealistic DPFUs). In about half of the stations these values were different in 2006. Those unrealistic, however, apparently were not at all harmful for calibration of EVN experiments (otherwise Cormac would complain). Thus we see that:

- **Stations do fit DPFU to measurements,**
- **DPFU lost its pristine meaning and the name is now misleading**

(unless we agree for it to mean 'Degrees Per **Fake** Unit').

Pros and cons of the DPFU use

Arguments for:

- Long tradition
- Incorporated in the FS, GNPLT, ANTABFS, and AIPS

Arguments against:

- **Complicates the overall picture of calibration process.** Presently, due to misleading nature of DPFU a newcomer has little chance to acquire in reasonable time (if at all) a feel of the EVN calibration idea, although in fact it is quite simple.
- **Is almost sure cause for the loss of Tcal and Tsys scaling**. This will happen when fitting DPFU to data within the GaiN PLoT (GNPLT) application. It is so just because there is no way to determine the absolute value of DPFU with this kind of observations (the CL experiments).

Note: In the GNPLT for checking the gain curve and DPFU we have a cascade submenu 'Fit to' with fitting options of 'New DPFU' and 'Gain Curve and DPFU'.

Possible actions to take

- First and foremost, stations should definitely

stop updating the value of DPFU with the GNPLT program, since doing so only modifies the unit of noise temperature (that supposedly once was Kelvin), whereas one is cheated to believe one has made some improvement. Therefore, it would be best if the next release of GNPLT had the option to fit DPFU disabled or outright removed.

- It would be beneficial to

set DPFU = 1 in every rxg file of each station. This way we would work only with the equivalent flux densities instead of temperatures. It would be an intermediate step preparing grounds for more concrete future solutions.

- In a more remote future, releases of FS, GNPLT and ABTABFS might completely do away with the DPFU quantity.

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