COMPUTING AND PROCESSING
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# Ionospheric Corrections

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The influence of the ionosphere on an East-West interferometer has been discussed in detail by Hinder & Ryle (1971), Strom (1972) and Spoelstra (1982).

There are two effects of concern: a phase advance which is due to the refractive index of the medium, and a rotation of the plane of polarization.

The critical quantity is the column density of electrons along the line of sight (TEC, total electron content): differential paths are produced for three reasons: the curvature of the spherical shell; diurnal gradients; and irregularities on a wide variety of scales. Fortunately, at the frequencies of the Compact Array the effects should be small. The LBA will require the simultaneous dual frequency operation if it is to achieve its full astrometric capabilities. Table I (from Hinder & Ryle) gives the scale of the problem.

Table I

Differential path length due to different kinds of ionospheric refraction for a source at an elevation of 30 deg, and an azimuth along the baseline. f = 1420 MHz. Path in cm.

| Baseline (km) | Irregularities (min) | (max) | Gradients | Curvature (solar min-max) |
|---|---|---|---|---|
| 1 | .03 | .04 | <.07 | .01-.7 |
| 10 | .3 | .4 | <.7 | .07-7.1 |
| 100 | 2.5 | 3.5 | <7.1 | .71-70.6 |

1. Ionospheric delay

$$\tau \sim -1.35E-7(n_t/f^2) \quad \text{secs, (SI units),}$$

where $n_t$ is the electron column density. (Note: the path length is decreased).

What value do we use for $n_t$ ?

1.1 The steady component

We treat the ionosphere as a spherical shell of thickness h (~ 350 km). Then $n_t$ is the vertical column density scaled up by the factor $\sec(z)(1 - h/(R\cos^2(z)))$. The vertical column density lies the range 1E16 to 1E17, solar minimum, night/day, and 1E17 to 1E18, solar maximum.

z is the zenith angle. (Measured at the lower level of the ionosphere: $R_e\sin(z_0) = (R_e+H)\sin(z)$, $z_0$ is the observed zenith angle). $R_e$ the earth's radius. H the height of the lower level

(~ 150 km);

R is the radius of the lower level of the ionosphere, (~6500km).

(We are assuming here frequencies well above the plasma frequency :- $f_0$ ~ 5MHz.)

The differential delay for an E-W baseline (B) is :

$$\Delta\tau = \tau(B/R_e)(\cos(\delta)\cos(\phi)\sin(T)/\sin(El))$$

T is the source hour angle, El is the source elevation.

At a frequency of 1420 MHz we could then expect a phase advance of order 100 turns under bad conditions. The differential phase shift for the CA (ie. the correction we apply) would be around 20 degrees. The LBA will have a bigger battle.

1.2 Diurnal gradients

Pronounced gradients can be expected at sunrise - $dn_t/dt$ = 1E17 el/$m^2$/hour have been observed at solar maximum.

The prospects for removing the refraction effects are not good. There are a number of possibilities:

a. Ionosonde data

Ionosonde data may be available from the IPS. Soundings are taken frequently (4/hour) at a number of stations around Australia. This data would be of great value in providing a baselevel for our corrections.

b. Dual frequency data (Day 1.1 ?).

Astrometry is possible. (It requires point sources, a not unreasonable prerequisite for astrometry).

$$\phi_1 = -\alpha/f_1 + 2\pi B f_1 \theta/c$$

$$\phi_2 = -\alpha/f_2 + 2\pi B f_2 \theta/c$$

from which we can get the source offset ($\theta$), and the column density ($\alpha/2\pi 1.35E-7$).

I suppose that a black belt MEMologist might consider processing dual frequency fields simultaneously, incorporating the ionospheric correction as a constraint.

c. Calibration sources.

Our present plan is to correct visibilities with the phase error detected on the nearest previously observed calibration source. This means that the ionospheric correction will largely be removed automatically; this poses a problem for the dispersion correction (see 1.4 below). I think that the modelling (d) will provide an adequate estimate of the largest component of the dispersion.

d. Faith, hope and lots of luck - Modelling.

put $f_0$ = 5 MHz, h = 350 km, then apply some seasonal and diurnal tweaks. Use a. and c. to guide the tweaking.

e. Self-cal.

For most frequencies of use (and certainly those of day 1) the tropospheric irregularities will likely be more of a problem. Self-calibration, which we expect will remedy these to some extent should also cope with the remaining ionospheric effects.

1.4 Should we correct the dispersion?

The refractive index is dispersive : $1/f^2$; the algorithm outlined above corrects for a dispersion-free index. This means that observations with wide bandwidths at 21 cm may experience an additional phase gradient, needing +/- 15% at the bandedges. (probably of order 2-4 degrees). This phase correction could be applied at the correlator, but does not seem warranted at the present stage of ignorance.

## 2. Faraday Rotation

This effect will be quite small, on average, at our frequencies; it affects all baselines - if uncorrected, our measured position angles for the plane of polarization would be too large by perhaps 5 degrees, at 1420 MHz.

$$\chi \sim 1.4E6(n_t/f^2)\langle B\rangle \text{ degrees (SI units)}$$

$\langle B\rangle$ is some average over the field/ray orientations; perhaps 0.5E-4 MKS. cf. Roger(1962). $n_t$ should be available from the refraction correction efforts. $\langle B\rangle$ could be estimated from careful polarization calibration observations.

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