The Parkes Spectral Line Baseline Problem - Will it be Exacerbated by the Upgrade?

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1 Introduction

There is a well-entrenched belief at the ATNF that high sensitivity spectral observations are compromised by the notorious "5.7 MHz baseline ripple". Since the ripple is due to multipathing between the focus cabin and the vertex, concern was naturally raised as to whether the enlarged focus cabin of the Parkes Upgrade would result in an increase in the magnitude of the ripple.

It transpires that a large amount of work was done on this problem, both here and overseas; the published record is, however, a bit sparse, as almost all the work is only recorded in internal reports. One gains the impression that the concensus (in the 70s) was that the problem was well understood, and that with care the problem could be tamed, resulting in good quality baselines. That collective wisdom appears to be evaporating.

A general summary of the baseline problem is given in section 2; in section 3 the Parkes-specific experiments are described. A detailed discussion of the Upgrade problem is given in section 4.

2 Previous Work

2.1 The problem

High sensitivity spectral line measurements have long been troubled with baseline problems, generally in the form of a quasi-sinusoidal variation ("ripple"). The periodicity suggests multipath interference with the secondary path length equal to twice the focal length.

A number of different mechanisms have been identified (Poulton, Morris), falling into two categories:

- Gain Chromatism. In this case the peak-to-peak ripple amplitude is proportional to the observed source intensity. This is the "ON-Source" component.
- Baseline Chromatism. This component is encountered even when the antenna is pointing at blank sky. This is the "OFF-Source" ripple.

Poulton evaluated this integral for the Parkes case, over a wide range of frequencies, for three levels of reflection from the feed - reproduced here as figure 1. It shows that at 5 GHz, for example, $\Gamma \sim -31dB$, leading to a (predicted) peak-to-peak $\Delta T/T_A$ of around 0.3%.

It is worth noting here that a pointing error can rapidly increase the reflected energy, and this will increase $\Delta T/T_A$.

The ripple may also depend of the source structure, as extended structure will spill past the feed and be scattered towards the main reflector.

Note also the general frequency dependance: $\Gamma \propto \lambda$

2.3 OFF-source component

The situation with the OFF-source component is much less secure. A number of mechanisms have been identified.

- Extended structure - ground radiation, atmosphere and the general background will present a distributed radiation flux to the feed area with ripple consequences much as for extended "ON-source" structure.
- A reflection of energy from the feed-receiver junction will lead to energy transmitted from the feed which may then scatter back to the feed and interfere. In this case the initial angular distribution of the scattered energy is well defined - it is the feed's pattern.

Estimating the amplitude of the OFF-source component is difficult. Morris and Poulton both presented arguments to show that the proposed mechanisms could produce a ripple of the observed magnitude but but the estimates and the observations have large errors.

2.4 Remedies and Strategies

- Local regions of high reflectivity. Flat plates normal to direct rays from the feed are likely to make a significant contribution to the ripple. These regions can in principle be identified from the periodicity of the ripple. Fisher (1978) used a reflectometer as a sharper tool to localise such trouble spots in the Greenbank antennas. The reflections can be moderated with absorber or by tilting the plate.

  While this approach will remove serious offenders it cannot address the reflection from the entire antenna.

- Vertex Corrector Assemblies. The integral expression for Γ is a vector sum over the entire reflector surface. A detailed examination of the contribution of the various sections of the reflector to the final vector sum shows that the central area makes a large contribution; that is, we can view the reflected signal as the sum of two roughly equal components: one from the central area and one from the rest of the antenna. Given this, we can alter the

Of little help:

- Placing absorber on the focus cabin ground-plane.
- Placing a cone around the feed in attempt to shield it from off-axis radiation.

In detail:

3.1 Vertex Corrector Assembly

Poulton (1974) designed a series of assemblies for the Parkes antenna, to cover a number of frequency ranges. The experience with the 3-9 GHz band assembly was disappointing: the fundamental was reduced by about 50%, but the other harmonics were unchanged. Considering that the first Fresnel zone has a radius of order 1m at 5GHz the balancing act required of the corrector assembly is enormous, so the mixed results are perhaps not surprising.

A simple cone (5 degree semi-angle) was found to be effective: the higher harmonics were essentially eliminated and the fundamental was reduced to $\Delta T/T_A \sim 0.5\%$. The ripple amplitude was independent of zenith angle.

The current corrector assembly is the cone.

3.2 Gaps at the 8.5m Radius

These gaps were left after the resurfacing campaign which provided a high precision "mm" surface in the inner 8.5m section. J.Murray showed that such a gap would make a significant contribution to the ripple - in effect we have a sizeable area of the antenna at constant phase from the feed.

The gaps have now been closed.

3.3 Noise Matching

Hard-won experience indicated that the baselines were improved if the ON and the OFF T_{sys} were made equal. It is possible that this process balanced the additional reflection at the receiver source flux density. It is not clear whether this technique is still required.

3.4 Hybrid Mode Feeds

The ripple will be reduced as the feed efficiency increases, so the switch to 2HE feeds should (and did) improve matters.

- The noise balancing operation should be revisited: is it a lost art, or an obsolete one?
- Attempt to reduce the scattered radiation from the tripod: the open structure is known to offer excellent scattering centres for strong off-axis sources. A smooth surface, tapered towards the vertex would have superior scattering properties.

6 References

This list is not comprehensive; nor have I been able to consult all the items; it provides some indication of what is available.

- Bania, Rood and Wilson (May 1993) - Frequency Baseline Structure in the 100m Telescope at 3.6cm Wavelength. MPIfR Technische Bericht N0. 75
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- Beiging and Pankonin - Experimental Investigation of the Causes of Spectroscopic Baseline Ripple at 5 GHz. MPIfR, Technische Bericht, No. 16
- Brockway (1984) - NRAO Electronics Div. Technical Rep. 126.
- Caswell - Spectral Line Observations with the Parkes Radio Telescope; some notes on Spurious Instrumental Effects. RPP 1675 (?)
- Fisher (1978) - Reflection Measurements on the 140ft and 300ft Radiotelescopes. NRAO Electronics Div. Internal Rep. 184
- Gardner (1.2.72) - Notes on Instrumental Effects on Spectral Line Receivers. (file note)
- Gardner (1973) - An investigation of Instrumental Effects with Spectral Line Observations with the 100m Telescope. MPIfR Internal Report
- Lockman and Rickard (1977) - Spurious Spectral Features at the NRAO 140 ft. NRAO Electronics Div. Internal report N0. 183
- Morris (Avril 1973) - Chromatism at Millimeter Wavelengths. Rapport Technique Provisoire; GI. mm/DM/No. 125
- Morris - Chromatism in Radio Telescopes due to Blocking and Feed Scattering, Internal Report, Observatoire de Paris, 92190, Meudon
- Morris (1974) - Chromatism and Antenna design. Internal Report, G.I. mm No. 125a
- Morris and Bieging (Jan. 1976) - Progress Report on Baseline Ripple Problem. MPIfR Internal Report

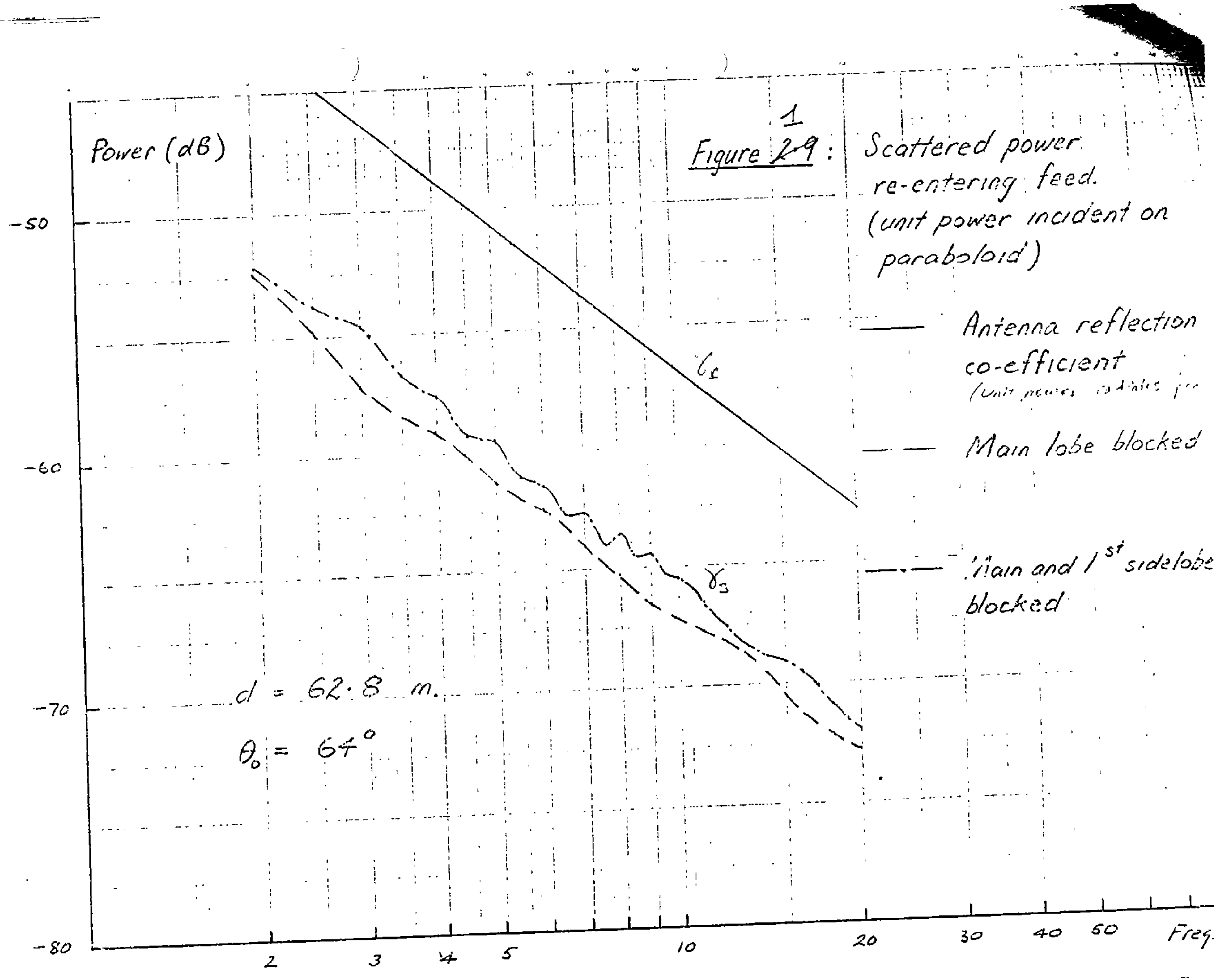
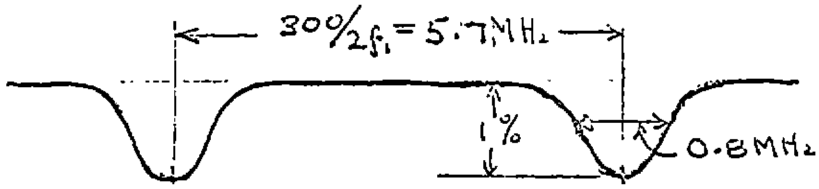
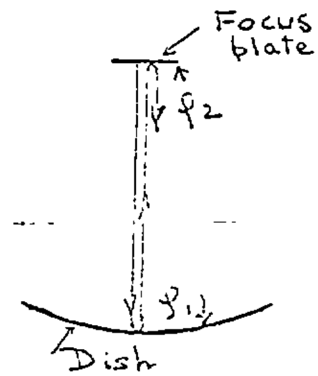

Power (dB)
-50
-60
-70
-80
2
3
4
5
10
20
30
40
50
Freq.
Figure 1 :
Scattered power re-entering feed. (unit power incident on paraboloid)
Antenna reflection co-efficient
Main lobe blocked
Main and 1st sidelobe blocked
$d = 62.8$ m.
$\theta_0 = 64°$
γ_s

Fig. 2

4. Multiple-reflection

It is possible for some of the aperture blockage to be reflected by the parabola and then reflected again by the blockage. This would give rise to higher modulation frequencies of the order of $2\nu_o$, $3\nu_o$ ..... if the blockage occurs in the vicinity of the focal plane. An effect ot this type has been observed with the Parkes 64-m dish at wavelengths of 9 cm and longer where apparent absorption "dips" of the form shown below were obtained.





These "dips" were explained as arising from multiple reflections between the parabola vertex and the flat plate of 3 - 4 m. size in the focal plane. If ρ_1 and ρ_2 are the reflection coefficients associated with waves so trapped, then successive reflections will add as

$$\text{constant} \left\{ 1 + |\rho_1 \cdot \rho_2| e^{-i\Delta} + |\rho_1 \cdot \rho_2|^2 e^{-i2\Delta} + \ldots\ldots \right.$$

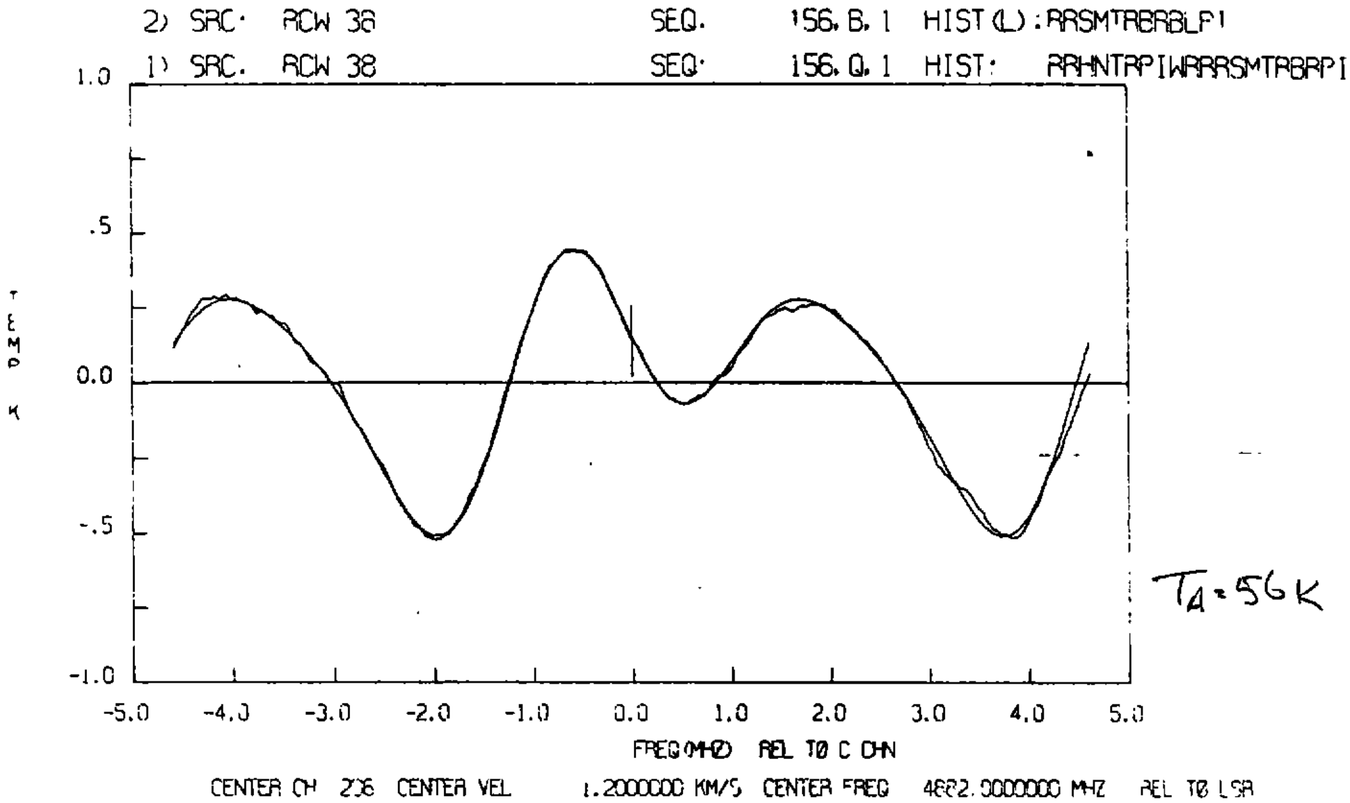
$$= \frac{\text{constant}}{1 - |\rho_1 \cdot \rho_2| e^{-i\Delta}}$$

, in which Δ is the phase difference associated with the round-path.

From the ratio of the half-widths of the "dips" to the spacing it was ascertained that $|\rho_1 \cdot \rho_2| \approx 0.8$. Such a high value is not impossible with a flat focal plane about a Fresnel zone in size.

By covering the focal plate with absorbing material the "dips" were removed. However, quasi-sinusoidal effects remained. At 6 cm the "dips" were not present, presumably because the focal plate was no longer a good reflector.

It is obvious that the radiation from multiple-reflections is associated with



Harmonic	P-P amplitude (K)
1	0.472
2	0.578
3	0.188
4	0.002

Fig. ~~16~~ 3 - Typical spectrum from Figure 15 and tabulation of calculated least-squares Fourier baseline components up to the fourth harmonic; Z.A. = 14°.5.

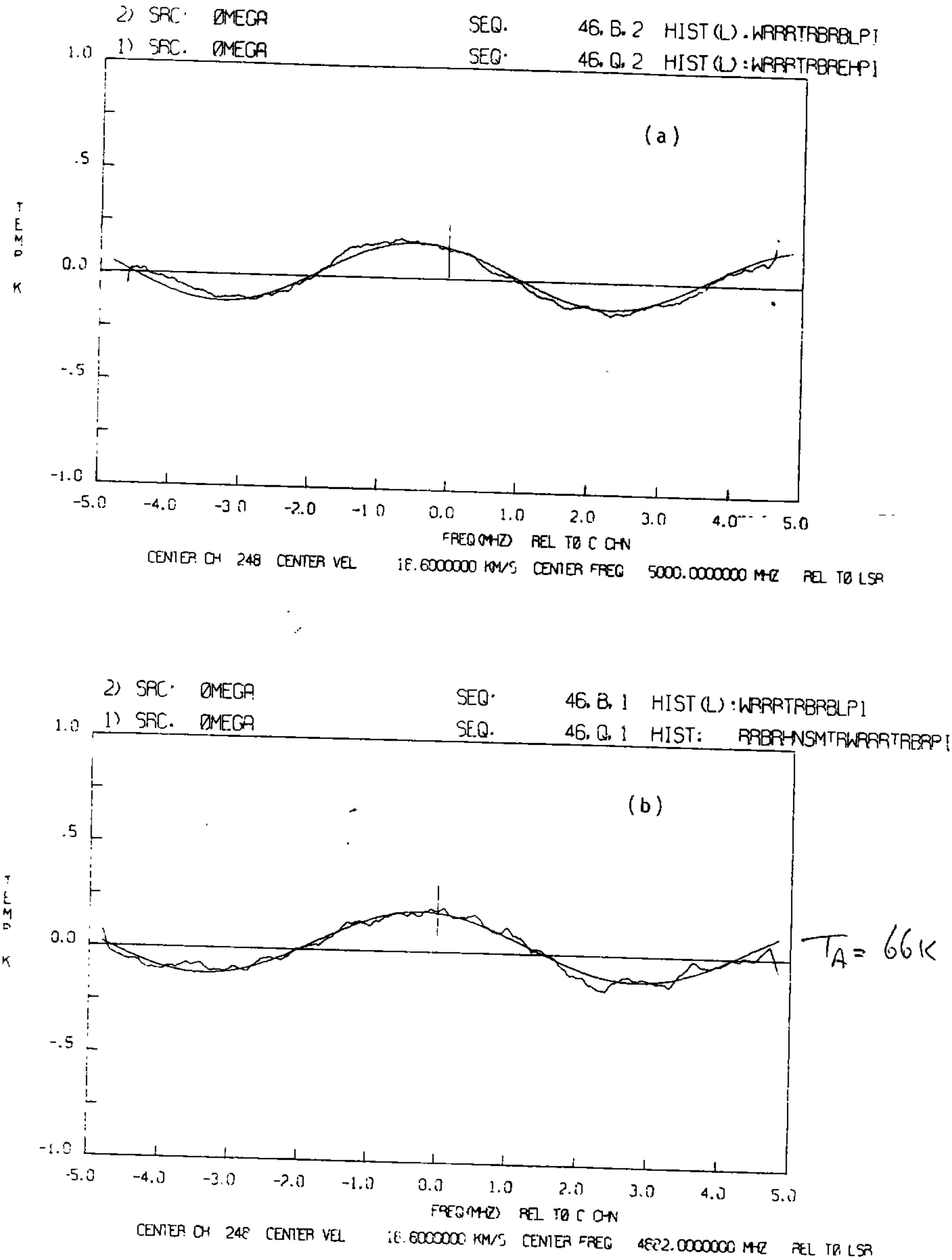


Fig. ~~23~~ 4 - Spectra obtained using scattering cone and MkI IHE feed; source M17 (Omega nebula), Z.A. = 45°; no focal plane absorber. (a) f_0 = 5000 MHz; (b) f_0 = 4882 MHz.