National Radio Astronomy Observatory

VLA Test Memo # 190

Why the "3 MHz" Ripple Moves With Time

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Antenna 1's ripple pattern was monitored over a 5 day period, using an averaging spectrum analyzer at the D-rack in the control building electronics room. The ripple pattern was printed out and the drift of one particular peak was tracked. Fig. 1 shows about 24 hours of this data for 940929-30. Timescale is MDT. Sunset was 18:58 and sunrise 07:04. The horizontal scale is 1" = 7.196 MHz. The ripple period is 3.45 MHz, corresponding to a length of 39.6 meters.

The change in the waveguide's average temperature can be calculated from the amount of shift in the location of a peak. This calculation (see next page) predicts a shift of .204 period or .704 MHz per C.

This shift was measured by following one peak over a 4-day period, and the corresponding temperature change was calculated. Fig. 2 shows this calculated change (lower curve) compared with the recorded ambient temperature (upper curve) recorded at the VLA weather station for that period.

The calculated curve follows the major features of the ambient curve very closely, showing the diurnal variation and the "cold snap" (thunderstorm?) after noon on Oct 1. Small-scale variations are smoothed out, and the peak-to-peak variation is roughly 71% of the ambient.

It is evident that the waveguide temperature follows the ambient very closely. Although a lag can be seen between ambient and waveguide temperatures when the curves are overlaid, it is small. Since about 1/3 of the waveguide is underground and presumably at constant temperature, its temperature variation of roughly 70% of the ambient temperature variation is reasonably consistent.

I conclude that the movement of the ripple pattern is due to thermal expansion (in length and diameter) of the 20mm waveguide, and that methods of controlling its temperature should be investigated.

CHANGE OF RIPPLE "PHASE" WITH TEMPERATURE

941006 PAL

Consider a transmission line with two discontinuities separated by a distance L. At some frequency f the round-trip path $2L$ will be N times the guide wavelength λ_g:

$$N = \frac{2L}{\lambda_g}$$

If L and/or λ_g changes, the change in N is

$$\Delta N = \frac{2\Delta L}{\lambda_g} - \frac{2L\Delta\lambda_g}{\lambda_g^2}$$

If α is the coeffecient of linear thermal expansion of the waveguide material, then $\Delta L = \alpha L \Delta T$. What is $\Delta\lambda_g$? λ_g is given by

$$\lambda_g = \frac{\lambda_0}{\sqrt{1 - \lambda_0^2/\lambda_c^2}}$$

Where $\lambda_0 = c/f$. The cutoff wavelength λ_c is proportional to the diameter a of the waveguide: $\lambda_c = ka$. Thus the guide wavelength will vary due to variations in the diameter of the waveguide. Since

$$\frac{d\lambda_g}{d\lambda_c} = \frac{-\lambda_g^3}{\lambda_c^3} \quad and \quad \frac{d\lambda_c}{dT} = k\alpha a = \alpha\lambda_c$$

we have

$$\frac{d\lambda_g}{dT} = \frac{-\alpha\lambda_g^3}{\lambda_c^2}$$

Combining terms and using $\lambda_g = c/\sqrt{f^2 - f_c^2}$ we get

$$\frac{\Delta N}{\Delta T} = \alpha L \frac{2f^2}{c\sqrt{f^2 - f_c^2}} = \alpha L K(f)$$

Some numbers for $a = 20$mm waveguide ($f_c = 18.3$ GHz):

Channel	f(GHz)	$K(f)$ (m^{-1})	ΔN/1C	$\Delta T/180°$
1	26.41	244	.156	3.2
2	28.79	248	.159	3.1
4	33.59	267	.171	2.9
8	43.91	322	.206	2.4

The next-to-last column gives the drift as a fraction of the ripple period for a 1C change in temperature. The last column gives the change in temperature required for a half-period drift of the ripple pattern.

The last two columns assume $\alpha = 16$ ppm/C (stainless steel) and $L = 40$ m.

2/103epsn Version 1.0 as of 940925
Data from: B:49291000.

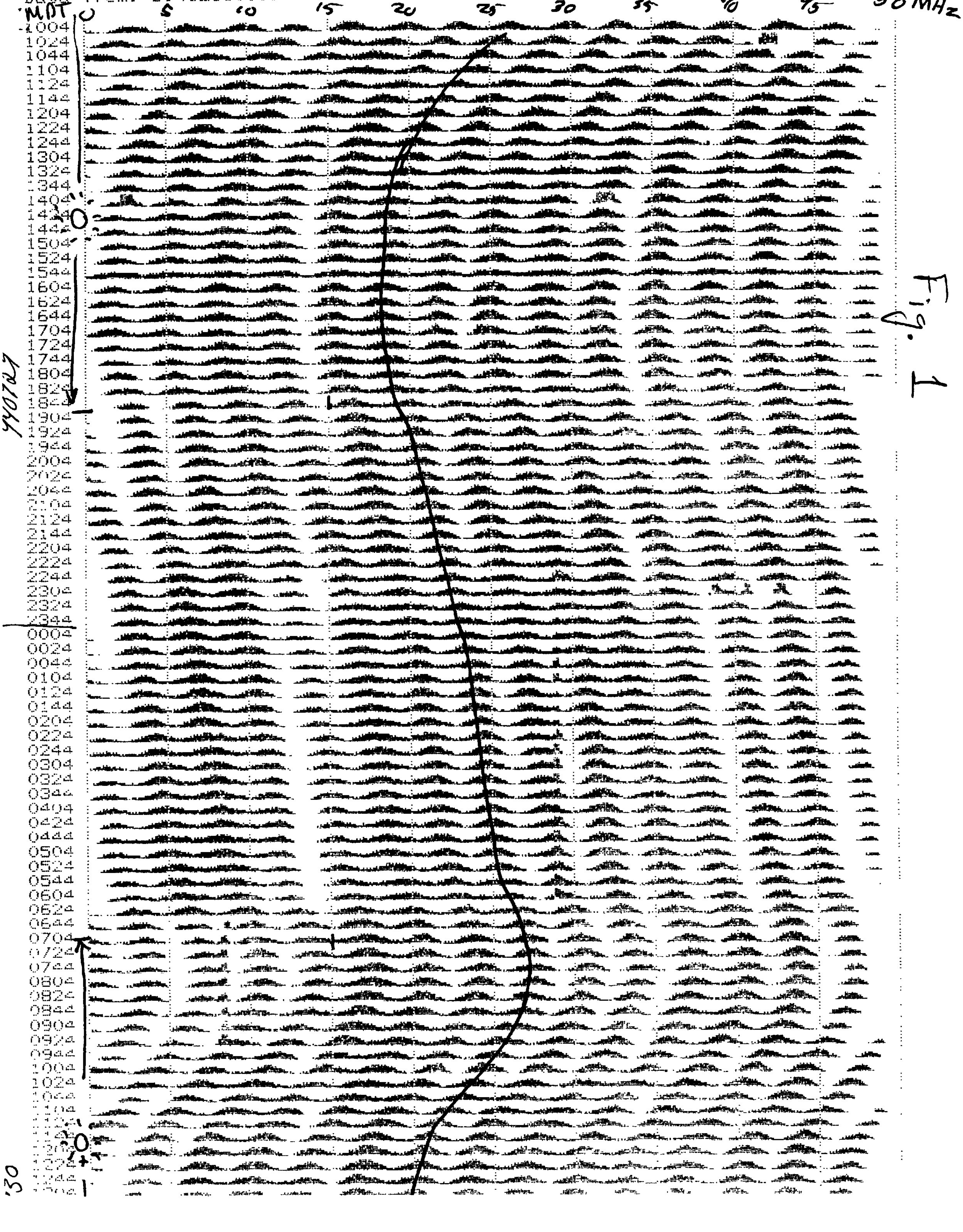
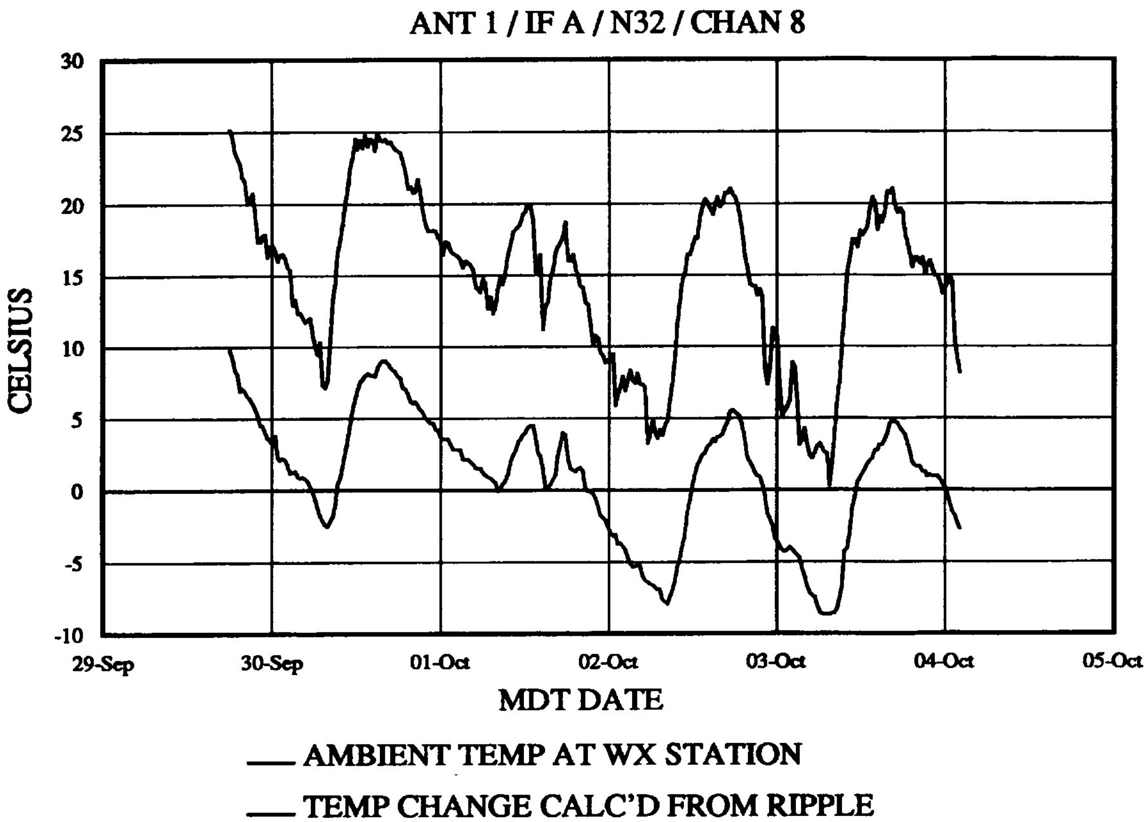


Fig. 1

Fig. 2


ANT 1 / IF A / N32 / CHAN 8
30
25
20
15
10
5
0
-5
-10
CELSIUS
29-Sep
30-Sep
01-Oct
02-Oct
03-Oct
04-Oct
05-Oct
MDT DATE
AMBIENT TEMP AT WX STATION
TEMP CHANGE CALC'D FROM RIPPLE