NATIONAL RADIO ASTRONOMY OBSERVATORY

VLA ELECTRONICS MEMORANDUM NO. 11

PHASE EQUALIZATION IN THE VLA IF SYSTEM

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Measurements of phase dispersion in 1 5/8" coaxial cable (VLA Electronics Memorandum No. 9, S. Weinreb) show a deviation from linear phase which is probably caused by coupling to a higher order mode. This coupling will occur as long as the cable has some attenuation. At any particular center frequency the phase can be expanded in a Taylor series:

$$\phi(\omega_o+\Delta\omega) = \phi(\omega_o) + \frac{d\phi}{d\omega}\bigg|_{\omega_o} \Delta\omega + \frac{1}{2}\frac{d^2\phi}{d\omega^2}\bigg|_{\omega_o} (\Delta\omega)^2 + \frac{1}{6}\frac{d^3\phi}{d\omega^3}\bigg|_{\omega_o} (\Delta\omega)^3 \;\ldots\ldots$$

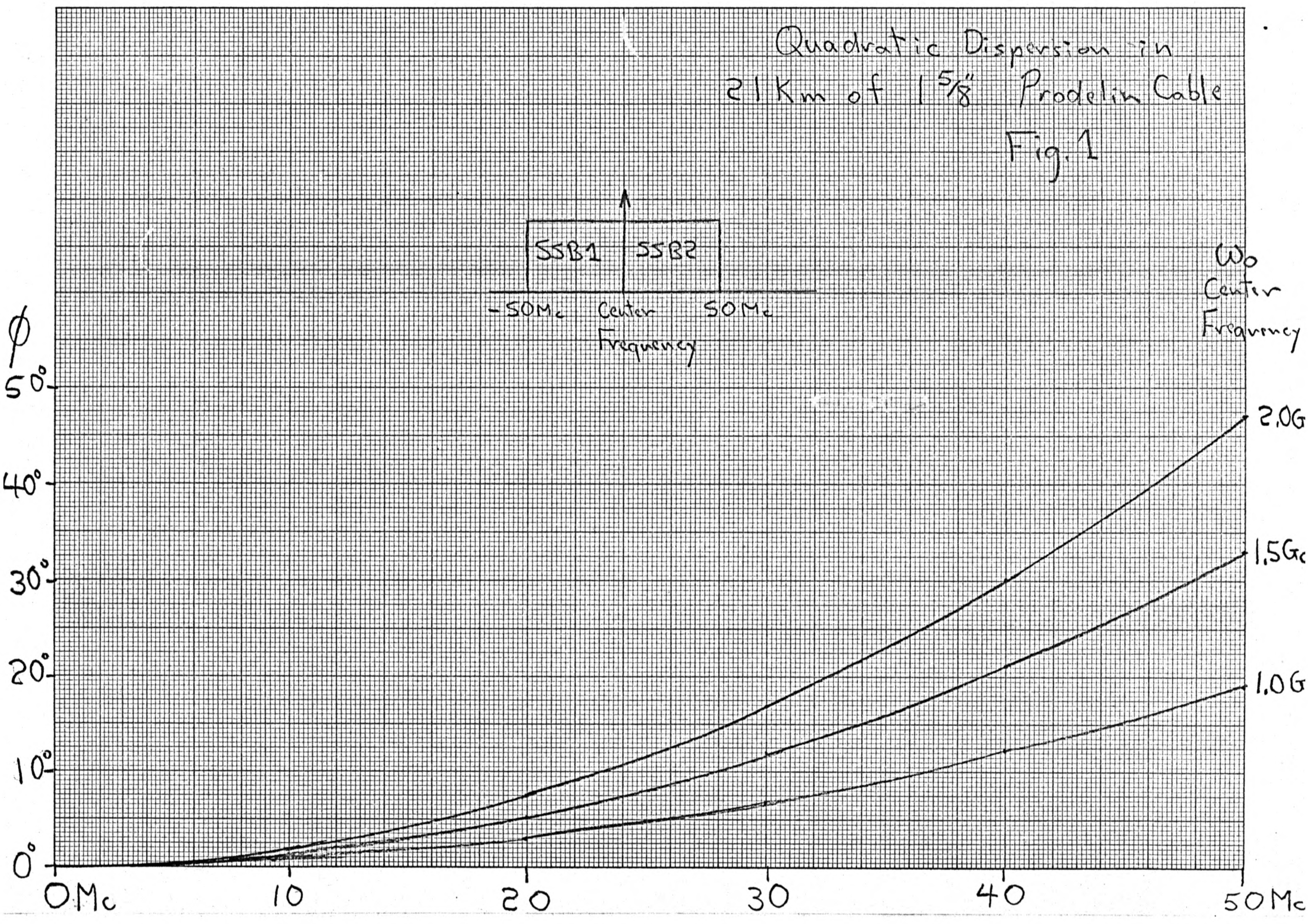
Consider the effect of this phase relationship on a modulated carrier. The first term is a constant phase shift which subtracts out when the carrier is detected. The second term represents the group delay of the modulation signal and is therefore non-dispersive. The third term is the Quadratic Dispersion, and while it cancels out in double side band modulation, it is present in single side band. We have plotted the Quadratic Dispersion in Fig. 1 for various center frequencies for a run of 21 Km of 1 5/8" Prodelin coaxial cable. This maximum dispersion is 50° for a carrier frequency of 2 Gc and will be less for lower frequencies and shorter lengths of cable. The fourth term in the Taylor series is the Cubic Dispersion which is less than 0.5°.

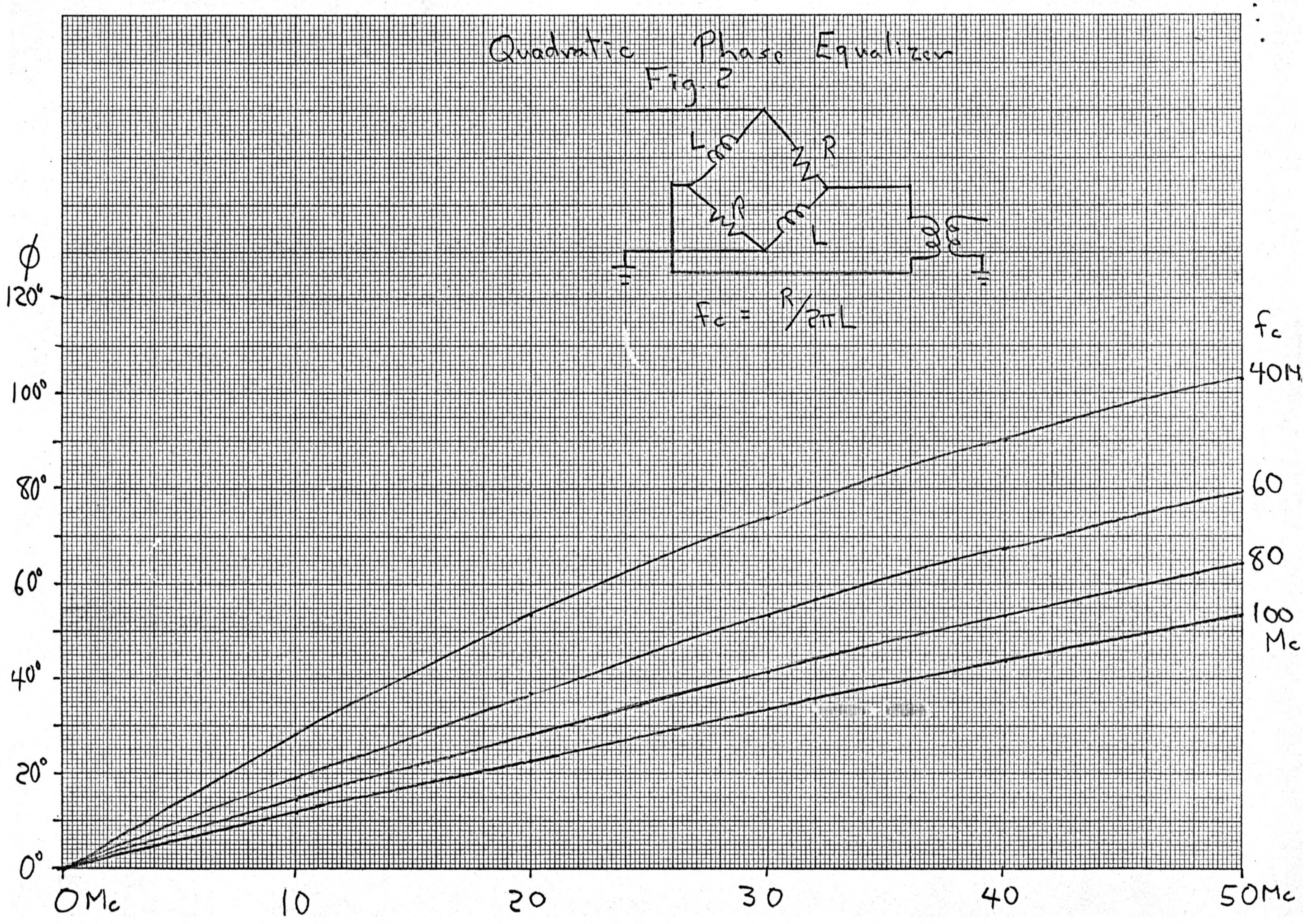
Since the telescopes will be tapped in at various points along the cable it is necessary to equalize for each telescope individually, rather than equalizing the entire cable. This can be done most conveniently by pre-equalization or post-equalization when the IF signal is at base band, i.e. 0 - 50 Mc. Note that the quadratic phase error is symmetric about the center frequency and hence has the same effect on the upper and lower sidebands. Hence, the equalization at base band is the same for both sidebands.

The simple all-pass network shown in Fig. 2 can be used for equalization. It has a voltage transfer whose amplitude is unity and whose phase is slightly non-linear. By adjusting the resistors in the network the amount of quadratic phase error can be varied to cancel that produced by the cable. The ratio of R/L which produces the minimum amount of deviation of the total phase (equalizer + cable) from linear phase is shown in Fig. 3. This network will reduce the phase non-linearity to less than 1°.

Since the network is a bridge it requires a transformer on the input or output in order to maintain a common ground. The phase characteristics of the transformer are important and should be measured while connected to the network. The voltage transfer of the network will be unity only if its output is lightly loaded, i.e. the source impedance of the preceding stage should be low and the input impedance of the next stage high. However, the network is adjustable for various amounts of quadratic phase error so that relaxing some of these requirements may mean just readjusting the network.

Some additional phase compensation may be necessary to correct for non-linear phase effects in the repeater amplifiers. Since these phase errors will again depend on where the telescope is tapped in on the cable, it is probably best to correct for the dispersion with the same network that is equalizing the cable phase. In general, one can probably ignore the Cubic Dispersion and just adjust for minimum Quadratic Dispersion.


Quadratic Dispersion in
21 Km of 1 5/8" Prodelin Cable
Fig. 1
SSB1
SSB2
-50Mc
Center
Frequency
50Mc
ω0
Center
Frequency
φ
50°
40°
30°
20°
10°
0°
2.0G
1.5Gc
1.0G
0Mc
10
20
30
40
50Mc


Quadratic Phase Equalizer
Fig. 2
L
R
R
L
Fc = R/2πL
φ
120°
100°
80°
60°
40°
20°
0°
fc
40M
60
80
100
Mc
0Mc
10
20
30
40
50Mc

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