PHASE LOCK LOOP AND ASSOCIATED COMPONENTS FOR THE RADIO FREQUENCY SYSTEM OF THE PF STORAGE RING PARTIII

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Filters are often necessary in electronic systems where undesired frequency components pollute the signal. The general design and construction of a band pass comb line filter which will be used in the rf system of the PF storage ring[1] is described here. Comb filters are easy to construct and give good electrical performance. These filters being small ($\lambda/8$ or less) also have the advantage of very broad stop bands above their primary pass bands. This type of filter consists of an array of resonating lines coupled together. The resonators are shorted at one end and the other end being loaded by a lumped capacitor. The theory and design of comb filters is well known[2]. However, a design modification which makes use of only n resonators (round rods) for a n pole filter will be used[3].

It is convenient to work out the design of resonator lines in terms of their capacitances to ground per unit length and the mutual capacitances per unit length between neighbouring lines (Figure 1). For $s \to \infty$, the characteristic impedance of a single line

$$Z_o = (60/\sqrt{\varepsilon_r}) \log (4b/\pi d)$$

and one obtains $\log \coth(\pi s/2b) = (Cab/\varepsilon)(60/\eta o)\{\log(4b/\pi d)\}^2$

The filter can be built with identical rods and choosing $Z_o = 70\ \Omega$ for optimum resonator Q, then $b/d = 2.52$,

we get $Cab/\varepsilon = 4.629 \log \coth (\pi s/2b)$

This gives the distance between rods (s/b) corresponding to the Cab's required. This is valid for relatively small fractional bandwidth (< 10%) filters. Instead of using additional bars for coupling to the 50 Ω input and output ports of the filter, tapping onto the first and the last rod is a practical way of producing the required loaded Q (loaded by resistor R) for the two resonators. The tapping point θ_1 from the short circuit end (Figure 2) can be obtained from the following equations

$$Q = \frac{R}{2Z}\frac{1}{\sin^2\theta_1}(\theta_o + \sin\theta_o\cos\theta_o) \quad \text{and} \quad Q = q_n \frac{f_o}{(bW)3dB}$$

θ_o is the electrical length of the resonators and q_n can be obtained from filter table. The tuning capacitor for center frequency ω_o (radious per second) is

$$C = Y_o/(\omega_o \tan\theta_o)$$

A band pass comb filter is to be designed with the specifications in Table 1. Choosing electrical length θ_o as $\pi/5$ radians and from curves and design formulae[2,4] The filter can be designed fully and the values are given in Table 2. The photograph of the actual filter is shown in Figure 3 and the measured electrical performance is listed in Table 1. Figure 4 shows the response of the filter over a sweep bandwidth of 4 to 1300 MHz. The deviation of 0.1 dB bandwidth from the designed value is due to tolerances on the physical dimensions of the filter. The performance of the filter is adequate for suppressing frequency components outside its 490±20 MHz bandwidth.

References

1) Photon Factory Design Manual (1979)
2) G.L. Matthae, L. Young and E.M.T. Jones, Microwave Filters, Impedance-Matching Networks and Coupling Structures, pp174-197, 497-519
3) D. Boussard, How To Design A Com Line Band-Pass Filter, CERN: LABII/RF/Int. Note/74
4) Reference Data For Radio Engineers, 177, Sixth Edition, Chapter 8

Table 1 Electrical Performance of the Filter

Filter Performance	Designed	Measured
Center frequency f_o MHz	490	490
0.1 dB ripple bandwidth MHz	4.95	2.5
3 dB bandwidth MHz	6.0	6.0
Rejection at ±20 MHz bandwidth dB	> 70	> 70
Insertion loss dB		7.1
Group delay nsecond		156
Input/Output VSWR		1.5:1

Table 2 Designed Physical Parameters of the Filter

Number of Resonators n	4
Distance Between Plates b	10
Diameter of Rods d	4
Length of Resonating Rods θ_o	61.22
Tapping Point From Short-End θ_1	5.85
Spacing Between Rods $S_{12} = S_{34}$	16.46
S_{23}	17.22
Value of Lumped Capacitor C^s PF	6.38
All Dimensions are in mm	

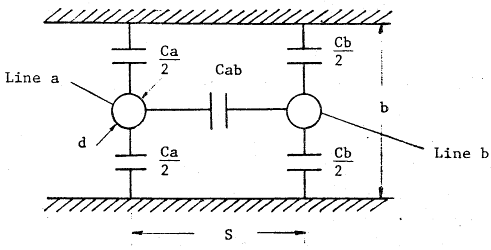

Figure 1 A Pair of Parallel-Coupled Lines

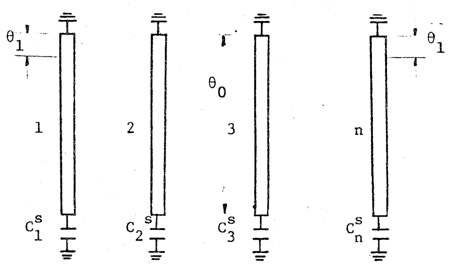

Figure 2 A Comb-Line n-Pole Band-Pass Filter

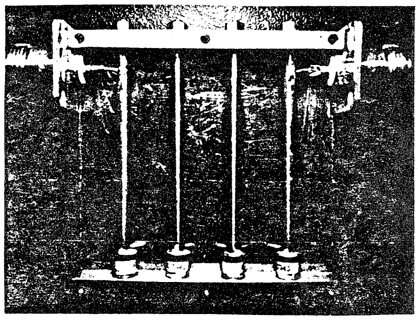

Figure 3 Photograph of the Actual Filter

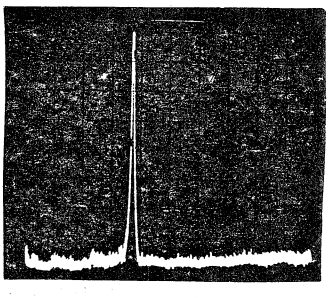

Figure 4 Amplitude Response for a Sweep Bandwidth of 4 to 1300 MHz. Vertical Scale 10 dB/div.