A Blumlein type modulator for a 100MW-class X-band klystron

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Abstract

To achieve the high efficiency in the X-band pulsed klystron modulator for the main linac in future X-band Linear Colliders, a new modulator with the Blumlein type PFN was fabricated and tested up to 450kV with the pulse transformer. Two identical 9-stage PFN's of the 23 ohm characteristic impedance are set on the both sides of the 1 to 7 step-up pulse transformer. High voltage tests showed that with this pulse transformer, 600 ns 450kV pulse of 250 ns rise time was successfully obtained. The test results of this Blumlein type modulator and the pulse transformer are presented.

Introduction

At the present status of the design studies and the R&D works dedicated to the next generation of the electron-positron linear colliders, the necessary RF power at the input of an x-band accelerating structure unit is around 100MW with the duration of 100 to 200ns, which is the sum of it's filling time and the bunch train(Ref-1,2). This means that even with the RF pulse compression scheme of factor 4, an X-band klystron pulse length is as short as 400-800ns. This operating pulse length is far shorter than that of an ordinary modulator which is widely used to drive present S-band klystrons. The ordinary modulator which is currently used as the power supply for the most of X-band klystrons cannot have the high power efficiency for the future linear collider due to the rather long rise and fall times of the cathode driving pulse. The switching speed is mainly determined by the stray capacitance and the leakage inductance of the pulse transformer in the present modulator system. To shorten the rise and fall times and improve the modulator efficiency raising the primary voltage thus relaxing the step-up ratio of the pulse transformer will be effective. The Blumlein type configuration of two identical PFN's can double the output voltage compared to the ordinary single stage PFN. This type of PFN has the advantage of introducing no new components such as a thyratron and a capacitor. To drive KEK's 100MW-class X-band klystrons named XB72k(Ref-3), the new Blumlein type PFN was fabricated and tested.

Design and parameters

Table-1a) and Table-1b) show the parameters of the Blumlein type PFN and it's 1-7 step up pulse transformer, respectively. Fig-1) shows the block diagram of the Blumlein type PFN. As reported in Ref-4) the rise time of this Blumlein PFN is mainly determined by the residual inductance of the lead wire in the capacitors. Two PFN's, 12-stages of Japanese capacitors and 9-stages of Maxwell capacitors respectively, were fabricated and tested. The parameters of the 12-stages PFN was reported in Ref-4). Fig-2a) and Fig-2b) show the simulation circuits for "SPICE" with the residual inductance of the capacitors supplied by Maxwell Co.. In Fig-2a) the inductance L109 and L209 which represent the residual inductance of the wiring between PFN and the pulse transformer(see Fig-3) are inserted to adjust the wave form to the test results. This reveals the fact that the inductance of the wiring limits the rise time of the PFN circuit. Fig-2b) shows the simulation pulse shape by "SPICE". The results showed that even with the residual inductance of 40nH due to the lead wire of the capacitance, the rise time of about 250nsec was successfully achieved.

Table-1a) PFN Specifications

Impedance	23 Ohms
Charging voltage(Max.)	86 kV
Pilse Width(Total)	700 ns
No. of stages	9 stages (x2sets)
Indactance/one stage	460 nH
Capacitance/stage	3.5 nF

Table-1b) Pulse transformer

Step-up ratio		1/7
Leakage L.		830 nH
Stray capacitance		4 nF
Loss at 200pps(Hysteresis)		100 W
	(Eddy Current)	1000 W
Rise time(Trans. only)		~100 ns
Fall time(Trans. only)		~200 ns
Sagging(500ns width)		2.8%
Core material	Si-Fe	25microns

Test Results

Fig-3) shows the Blumlein PFN and 1-7 step up pulse transformer set in it's oil tank. The load was 1k-ohm high voltage resister which is set in the same oil tank. The PFN was fired by the double pulse mode to achieve the resonant charging process and to avoid the excessive heating of the load resister which has no cooling method. Two PFN's were tested up to 480kV output at the secondary winding of the pulse transformer and the 9-stages PFN with the Maxwell capacitors showed faster rise time than the 12 stages PFN. Apparently, this difference was the result of the smaller inductance of Maxwell capacitors. To achieve the fast rise time and the flat top, ground wiring and the inductance of the PFN were trimmed several times. The wave form achieved in this high voltage run is shown in Fig-4). The output voltage reached to 350kV and the rise time of 270nsec was successfully achieved.

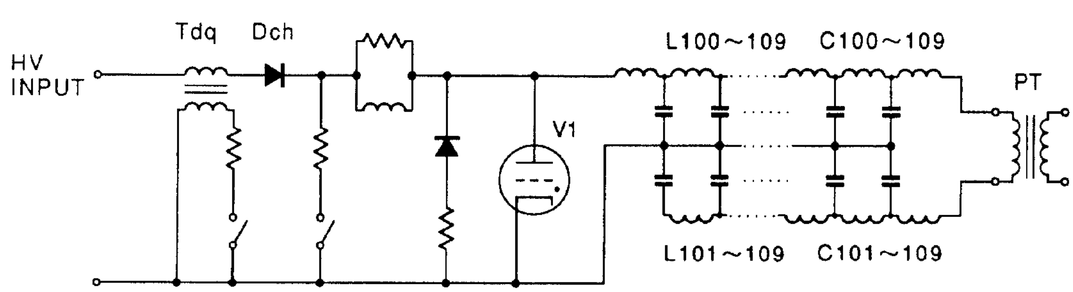
Discussions

The high voltage test results shown in Fig-4) are in good agreement with the simulation by the use of "SPICE" shown in Fig-2b). It can be concluded that the main factor which limits the rise time of the pulse were the stray inductance of the lead wire in the capacitance and some wiring between PFN and the thyratron and/or between PFN and the pulse transformer. To achieve the rise time shorter than 270nsec obtained in this Blumlein PFN, Design and the fabrication of 16-stages PFN's in oil tank is under progress. In this new version, all circuits shown in Fig-1 are to be set in one oil tank, therefore the limiting factor such as an inductance of the several wiring between parts of in the system could be substantially reduced.

References)

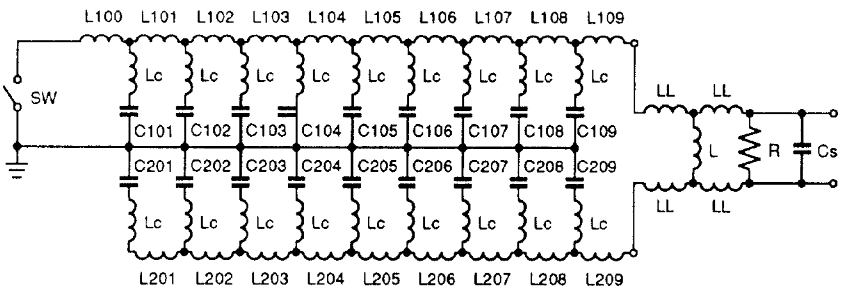
1)"JLC-1"; KEK Report 92-16(1992)
2)K.Takata; Proc. of HEACC92, Hamburg(1992)p.811.
3)H.Mizuno el al.; Prc.of 1992 Linear Accelerator Conference. 1992 Aug. Ottawa, Ontario, Canada; p127.
4)H.Mizuno et al.; Proc of the 1993 Particle Accelerator Conference; p1321.

Fig-1) A schematic of the Blumlein Type PFN's



L100 = 920nH
L101~109 = 460nH
L201~209 = 460nH
C101~109 = 3.5nF
C201~209 = 3.5nF
V1 : Thyratron(CX1937A ; EEV)

Fig-2a) The equivalent circuit for "SPICE"



C101~C109 = 3.5nF
C201~C209 = 3.5nF
Lc = 40nH
L100 = L109 = 1063nH
L101 = L108 = 533nH
L102 = L107 = 503nH
L103 = L106 = 463nH
L104 = L105 = 443nH
L201~L209 = 463nH
LL= 215nH
L= 225uH
R= 23 ohm
Cs= 4.738nF

Fig-2b) "SPICE" output

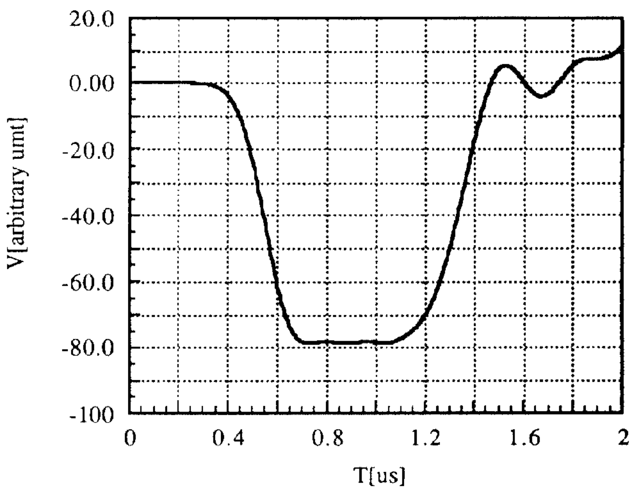


Fig-3) Blumlein PFN and Pulse Trans. Tank

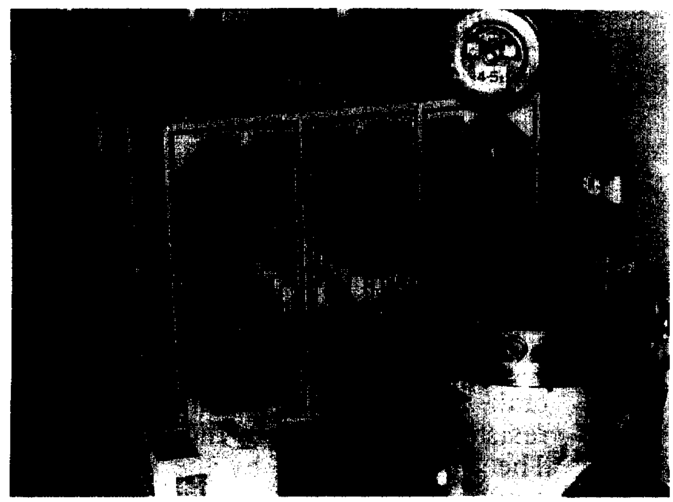


Fig-4) 9-stages PFN's output (Ch4 350kV peak)