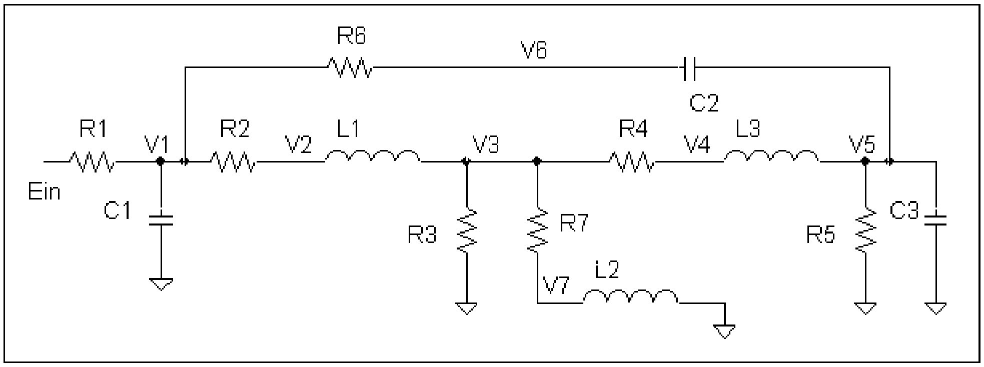
Model of Broadband Pulse Transformer –

In this model, L1 and L3 represent leakage inductance's and L2 is the magnetizing inductance. The capacitors represent interwinding parasitics, and the resistors represent ESR's. The output is taken from C3.



Summing the currents at each node: (Since V1 = E1 = 1V, also I1 = L1 current = 1A)

Node V1 = E1: $\frac{Ein - E1}{R1} = i_{C1} + i_{C2} + I1$, or $i_{C1} + i_{C2} = \frac{Ein}{R1} - \frac{E1}{R1} - I1$

From this first equation, we fill in the first row of A1 and B2. Since V1 = E1 = 1V, and V5 = E3 = 1V, the unknowns are:

```
V2 V3 V4 V6 V7 iC1 iC2 iC3 eL1 eL2 eL3    Column label sequence
```

$$A1_1 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 \end{bmatrix}$$

```
E1  E2 E3  I1  I2 I3 Ein     Column label sequence
```

$$B2_1 = \begin{bmatrix} \frac{-E1}{R1} & 0 & 0 & -I1 & 0 & 0 & \frac{Ein}{R1} \end{bmatrix}$$

Note that we can place E1, E2, I1, I2, etc, in the B2 array since they are known's (all = 1). Ein = 1V but can be other constant known values.

This process continues with the 2nd equation from node V2:

Node V2 $\frac{E1 - V2}{R2} = I1$, or $\frac{V2}{R2} = \frac{E1}{R2} - I1$

```
V2 V3 V4 V6 V7 iC1 iC2 iC3 eL1 eL2 eL3    Column label sequence
```

$$A1_2 = \begin{bmatrix} \frac{1}{R2} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

```
E1  E2 E3  I1  I2 I3 Ein     Column label sequence
```

$$B2_2 = \begin{bmatrix} \frac{E1}{R2} & 0 & 0 & -I1 & 0 & 0 & 0 \end{bmatrix}$$

The procedure should now be clear. The remaining equations are:

Node V3 $\qquad I1 = \dfrac{V3}{R3} + I2 + I3, \quad \text{or} \quad \dfrac{V3}{R3} = I1 - I2 - I3$

Node V4 $\qquad \dfrac{V3 - V4}{R4} = I3, \quad \text{or} \quad \dfrac{V3}{R4} - \dfrac{V4}{R4} = I3$

Node V5=E3 $\qquad I3 + i_{C2} = \dfrac{E3}{R5} + i_{C3}, \quad \text{or} \quad i_{C2} - i_{C3} = \dfrac{E3}{R5} - I3, \quad (E3 = V5)$

Node V6 $\qquad \dfrac{E1 - V6}{R6} = i_{C2}, \quad \text{or} \quad \dfrac{V6}{R6} + i_{C2} = \dfrac{E1}{R6}$

Node V7 $\qquad \dfrac{V3 - V7}{R7} = I2, \quad \text{or} \quad \dfrac{V3}{R7} - \dfrac{V7}{R7} = I2$

U = 5, N = 6, hence U+N = 11 equations are required. We need four more.

$V6 = E2 + E3; \quad V2 - V3 - e_{L1} = 0;$
$e_{L2} - V7 = 0; \quad V4 - e_{L3} = E3$

Simple bookkeeping task: Fill in the columns of A1 from the LH side of these equations.
Note: This circuit is not more complex, the procedure is the same; it's just bigger!

```
V2   V3   V4   V6   V7 iC1 iC2iC3 eL1 eL2 eL3     Column label sequence
 1    2    3    4    5   6  7  8    9  10  11      Column number
```

$$A1 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 \\ \frac{1}{R2} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \frac{1}{R3} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \frac{1}{R4} & \frac{-1}{R4} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{R6} & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & \frac{1}{R7} & 0 & 0 & \frac{-1}{R7} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \end{bmatrix}$$

Fill the columns of B2 from the RH side of the above equations:.

```
E1  E2  E3   I1 I2  I3  Ein        B2 column labels
1   2   3    4  5   6   7         Column number
```

$$B2 = \begin{bmatrix} \frac{-1}{R1} & 0 & 0 & -1 & 0 & 0 & \frac{1}{R1} \\ \frac{1}{R2} & 0 & 0 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & -1 & -1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & \frac{1}{R5} & 0 & 0 & -1 & 0 \\ \frac{1}{R6} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$P = \mathrm{diag}\left[C1 \quad C2 \quad C3 \quad L1 \quad L2 \quad L3\right]$ Same sequence as E1, E2, E3, I1, I2, I3

The ac response plot shows a flat frequency response from about 1KHz to 10MHz (See ac plot following). To prevent a distorted output pulse, the rise time of the input pulse should be greater than

$$tr = \frac{\ln(3)}{\pi \cdot 10MHz} = 35ns$$

The rise time of the input pulse is 10ps, hence the output at C3 will be distorted as is shown on the transient response plot.

Output from M-file xfrmrds2.m: Execution time: 14 seconds (2GHz Pentium 4)