General.

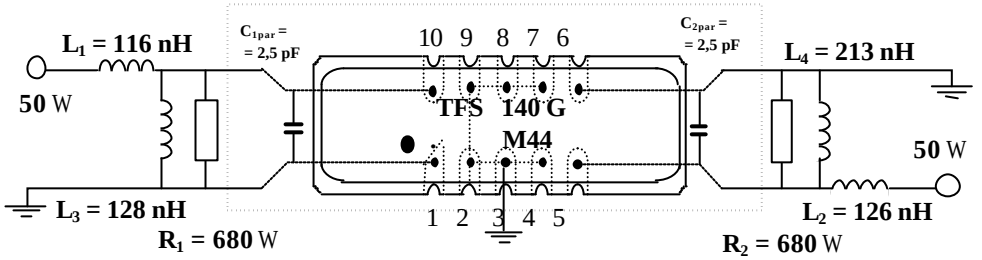
The filter can be driven in an unbalanced way. It is matched to **50** Ω
The matching element values given below are theoretical calculations based on measured values for termination impedance, given in the specification and S-parameters of the filters on PCB. If there are parasitics on the customer PCB, the matching elements have to be optimised regarding the circuit and PCB design.
We have tested on the PCB (tft032) two different versions of matching network with shunt resistances.

Unbalanced matching.

We have tested two unbalanced matching networks with reactance elements and with shunt resistance (scheme 1 and 2).
The calculation was made with consideration of parasitics. The capacities of C_{1par} and C_{2par} are used for simulation of parasitics effect of our PCB (tft032) only.

1. Theoretical matching. Scheme 1.

The values of the matching elements, which are given on the below diagram, are calculated for ILo ≈ - 18...-19 dB with consideration of the Q-values = 70...100 (our SMD-elements) and parasitics capacities C_{1par}; C_{2par} = 2,5 pF and based on measured S-parameters of the filter TFS 140G.



Scheme 1. Theoretical matching with Q = 70

The below table shows how termination impedances (input and output) and insertion loss depend on different Q-values of SMD matching elements with constant reactance part of matching elements from above diagram .

	Input termination impedance		Output termination impedance		ILo
Q	Rp II – Cp [Ω] II [pF]	R + j X [Ω]	Rp II – Cp [Ω] II [pF]	R + j X [Ω]	[dB]
ideal	186,60 II -16,603	22,1 +j 60,3	206,08 II -12,090	35,5 +j 77,8	-17,2
200	184,24 II -16,567	22,4 +j 60,3	203,92 II -12,058	35,9 +j 77,7	-17,6
150	183,47 II -16,555	22,5 +j 60,2	203,22 II -12,047	36,0 +j 77,6	-18,0
100	181,96 II -16,530	22,7 +j 60,2	201,82 II -12,025	36,3 +j 77,5	-18,2
70	**180,06 II -16,499**	23,0 +j 60,1	**200,07 II -11,997**	36,7 +j 77,4	**-18,5**
50	177,59 II -16,456	23,3 +j 60,0	197,79 II -11,959	37,1 +j 77,2	-18,9
30	172,16 II -16,352	24,1 +j 59,8	192,74 II -11,868	38,2 +j 76,8	-19,4
20	165,92 II -16,218	25,1 +j 59,5	186,90 II -11,750	39,5 +j 76,3	-19,9

The next tables 1 and 2 show how matching elements L_1 , L_2 , L_3 and L_4 depend on different Q-value and different parasitics capacities (C_{1par} , C_{2par}) on a PCB.
Simulated termination impedances are constant : for input : 180 Ω || - 16,5 pF
for output: 200 Ω || - 12,0 pF

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Table 1 ($R_1 = R_2 = 680\ \Omega$, $C_{1par} = C_{2par} = 2{,}5$ pF)

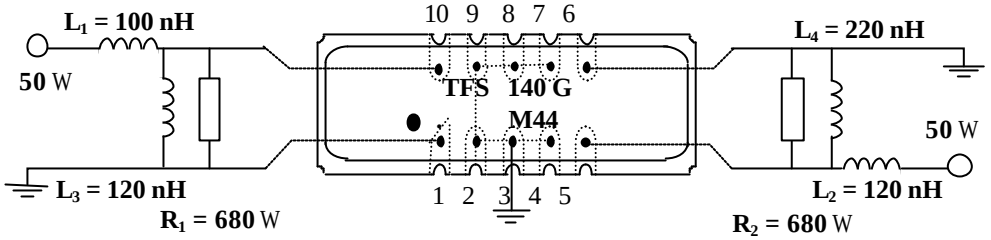
Input matching values			Output matching values		
Q-value	L_1 [nH]	L_3 [nH]	Q-value	L_2 [nH]	L_4 [nH]
ideal	112,2	131,4	ideal	122,8	221,6
200	113,4	130,2	200	123,9	218,5
150	113,8	129,8	150	124,2	217,5
100	114,6	129,0	100	125,0	215,5
70	**115,7**	**127,9**	**70**	**126,0**	**213,0**
50	117,2	126,5	50	127,3	209,6
30	120,9	123,3	30	130,7	202,1
20	126,1	119,3	20	135,3	193,1

Table 2 ($R_1 = R_2 = 680\ \Omega$, Q = 70 = const.)

Input matching values			Output matching values		
C_{1par} [pF]	L_1 [nH]	L_3 [nH]	C_{par2} [pF]	L_2 [nH]	L_4 [nH]
1,5	115	142	1,5	126	256
1,7	115	139	1,7	126	246
1,9	116	136	1,9	126	237
2,1	116	133	2,1	126	228
2,3	116	131	2,3	126	220
2,5	116	128	2,5	126	213
2,7	116	125	2,7	126	206
2,9	116	123	2,9	126	200
3,1	116	121	3,1	126	194
3,3	116	118	3,3	126	188

1.1 Matching on the PCB. Scheme 1.

The matching networks on the our test board (PCB – tft032) was tested with SMD-components with Q-value of ≈ 70. Matching elements values are given below :



Scheme 1. PCB –1 (SMD Q = 70)

Filter has next typical values with unbalanced scheme 1 :

ILo (typ.) = - 18,6...18,9 dB
Group delay ripple in (F_C – 0,85 MHz ... F_C + 0,85 MHz) = 140...160 ns (p-p).
Phase ripple in (F_C – 0,85 MHz ... F_C + 0,85 MHz) = 3°...4° (p-p).
Triple transit signal = 41...42 dB
VSWR(S_{11}) in (F_C – 0,85 MHz ... F_C + 0,85 MHz) ≈ 1,7 : 1
VSWR(S_{22}) in (F_C – 0,85 MHz ... F_C + 0,85 MHz) ≈ 1,7 : 1

Filter response is shown in Appendix 1 .

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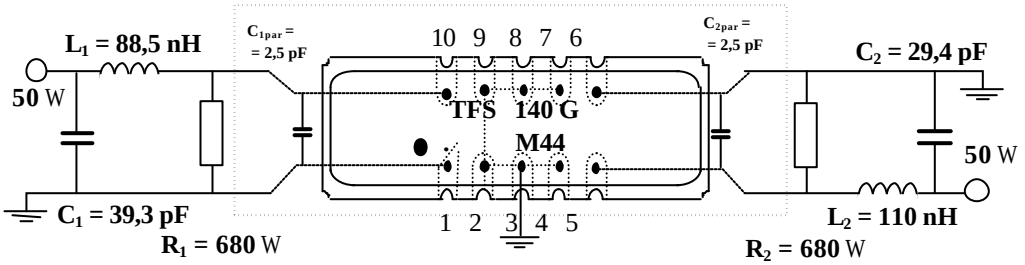
2. Theoretical matching. Scheme 2.

The values of the matching elements, which are given on the below diagram, are calculated for ILo ≈ -18...-19 dB with consideration of the Q-values = 70...100 (our SMD-elements) and parasitics capacities C_{1par}; C_{2par}= 2,5 pF and based on measured S-parameters of the filter TFS 140G.



Scheme 2. Theoretical matching with Q = 70

The below table shows how termination impedances (input and output) and insertion loss depend on different Q-values of SMD matching elements with constant reactance part of matching elements from above diagram .

	Input termination impedance		Output termination impedance		ILo
Q	Rp II – Cp [Ω] II [pF]	R + j X [Ω]	Rp II – Cp [Ω] II [pF]	R + j X [Ω]	[dB]
ideal	190,4 II -16,771	21,4 +j 60,2	208,2 II -12,205	34,7 +j 77,6	-17,2
200	186,6 II -16,677	22,0 +j 60,1	205,2 II -12,134	35,4 +j 77,5	-17,6
150	185,4 II -16,645	22,2 +j 60,1	204,2 II -12,11	35,6 +j 77,5	-18,0
100	183,0 II -16,581	22,5 +j 60,1	202,3 II -12,062	36,1 +j 77,4	-18,2
70	**180,0 II -16,499**	23,0 +j 60,1	**200,0 II -12,000**	36,6 +j 77,4	**-18,5**
50	176,3 II -16,388	23,6 +j 60,1	197,0 II -11,917	37,4 +j 77,3	-18,9
30	168,4 II -16,126	25,1 +j 60,0	190,6 II -11,722	39,2 +j 77,0	-19,4
20	160,0 II -15,792	26,9 +j 59,9	183,5 II -11,475	41,4 +j 76,7	-19,9

The next tables 1 and 2 show how matching elements **C_1 , L_1 , C_2** and **L_2** depend on different Q-value and different parasitics capacities (**C_{1par} , C_{2par}**) on a PCB.
Simulated termination impedances are constant : for input : 180 Ω || - 16,5 pF
for output: 200 Ω || - 12,0 pF

Table 1 ($R_1 = R_2 = 680\ \Omega$, $C_{1par} = C_{2par} = 2{,}5$ pF)

Input matching values			**Output matching values**		
Q-value	C_1 [pF]	L_1 [nH]	Q-value	C_2 [pF]	L_2 [nH]
ideal	36,83	89,59	ideal	27,67	110,67
200	37,66	89,22	200	28,27	110,41
150	37,95	89,10	150	28,47	110,33
100	38,53	88,85	100	28,89	110,15
70	39,31	88,52	70	29,44	109,91
50	40,40	88,07	50	30,20	109,58
30	43,16	86,99	30	32,11	108,77
20	47,15	85,57	20	34,81	107,66

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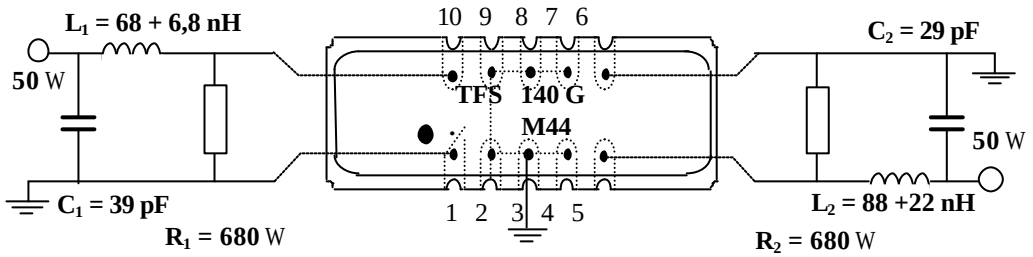
Table 2 ($R_1 = R_2 = 680\ \Omega$, Q = 70 = const.)

Input matching values			Output matching values		
C_{1par} [pF]	C_1 [pF]	L_1 [nH]	C_{par2} [pF]	C_2 [pF]	L_2 [nH]
1,5	36,5	92,5	1,5	26,2	115,7
1,7	37,1	91,7	1,7	26,8	114,5
1,9	37,6	90,9	1,9	27,5	113,3
2,1	38,2	90,1	2,1	28,2	112,2
2,3	38,8	89,3	2,3	28,8	111,0
2,5	39,3	88,5	2,5	29,4	109,9
2,7	39,9	87,8	2,7	30,1	108,8
2,9	40,4	87,0	2,9	30,7	107,7
3,1	41,0	86,3	3,1	31,3	106,6
3,3	41,5	85,5	3,3	32,0	105,5

2.1 Matching on the PCB. Scheme 2.

The matching networks on the our test board (PCB – tft032) was tested with SMD-components with Q-value of ≈ 70. Matching elements values are given below :



Scheme 2. PCB-2 (SMD Q = 70)

Filter has next typical values with unbalanced scheme 2 :

ILo (typ.) = - 18,6...18,9 dB
Group delay ripple in (F_C – 0,85 MHz ... F_C + 0,85 MHz) = 160...180 ns (p-p).
Phase ripple in (F_C – 0,85 MHz ... F_C + 0,85 MHz) = 3°...4,6° (p-p).
Triple transit signal = 40,5...41,5 dB
VSWR(S_{11}) in (F_C – 0,85 MHz ... F_C + 0,85 MHz) ≈ 1,7 : 1
VSWR(S_{22}) in (F_C – 0,85 MHz ... F_C + 0,85 MHz) ≈ 1,7 : 1

Filter response is shown in Appendix 2 .

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Commentary.

All matching networks on the PCB does slightly differs from the theoretical matching. The reasons for that are parasitics of the PCB (parallel capacities $\mathbf{C_{1par}}$, $\mathbf{C_{2par}}$ and serial inductors of microstrip on the our board tft032), and particularly differences in the Q-value of the matching components.
But if the parasitics on the customer board (mentioned parasitics, additional parasitics of active parts) are different to this PCB (tft032), the matching elements will have to be slightly adjusted. Both in line and shunt elements will change both pass band shape (tilt, concave, convex) and insertion loss ILo.

Details.

Insertion loss depends much on parallel matching elements, Q-value of matching elements and parasitics capacities on board (PCB).

Pass band shape characteristic **[S_{21} , S_{11} , S_{22} , tilt in pass band]** depends much on series elements for all schemes 1 and 2 : $\mathbf{L_1}$ and $\mathbf{L_2}$.
Both in each side (input and output) have to be adjusted on your board design.

Insertion loss, group delay ripple and return loss depend on shunt resistances $\mathbf{R_1}$, $\mathbf{R_2}$ and parallel matching elements: $\mathbf{L_3}$ and $\mathbf{L_4}$ for scheme 1 ;
$\mathbf{C_1}$ and $\mathbf{C_2}$ for scheme 2 .

Comparison of matching schemes:

Electrical characteristics of the filter TFS 140G are equals in F_C ... F_C ± 45 MHz for all matching networks.

Scheme 2 with parallel capacities $\mathbf{C_1}$ and $\mathbf{C_2}$ have better selection in F_C + 80 MHz ... F_C + 125 MHz as compared with schemes 1 with parallel inductors $\mathbf{L_3}$ and $\mathbf{L_4}$.

Scheme 1 is more stable for filter characteristic in the pass band, than scheme 2 because relative accuracy (tolerance) of matching series elements for the scheme 1 are larger (≈ 5...8 % for element $L_{1,2}$ and ≈ 10 % for element $L_{3,4}$), than for scheme 2 (≈ 1...3 % for element $L_{1,2}$ and ≈ 5 % for element $C_{1,2}$).

Shunt resistances are used to improve VSWR(S11, S22).

Additional note.

We can send to you filter sample TFS 140G on our PCB (tft032) according to your requirements : scheme 1 or 2.

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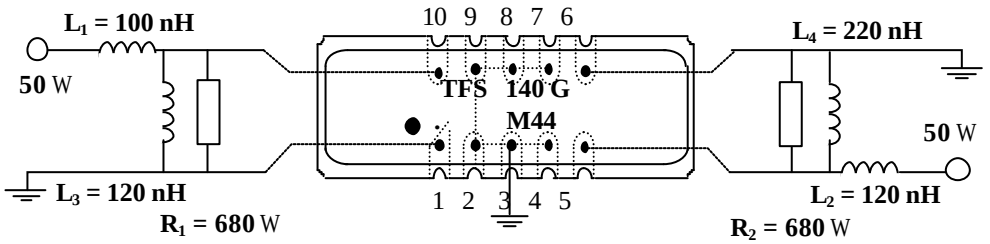
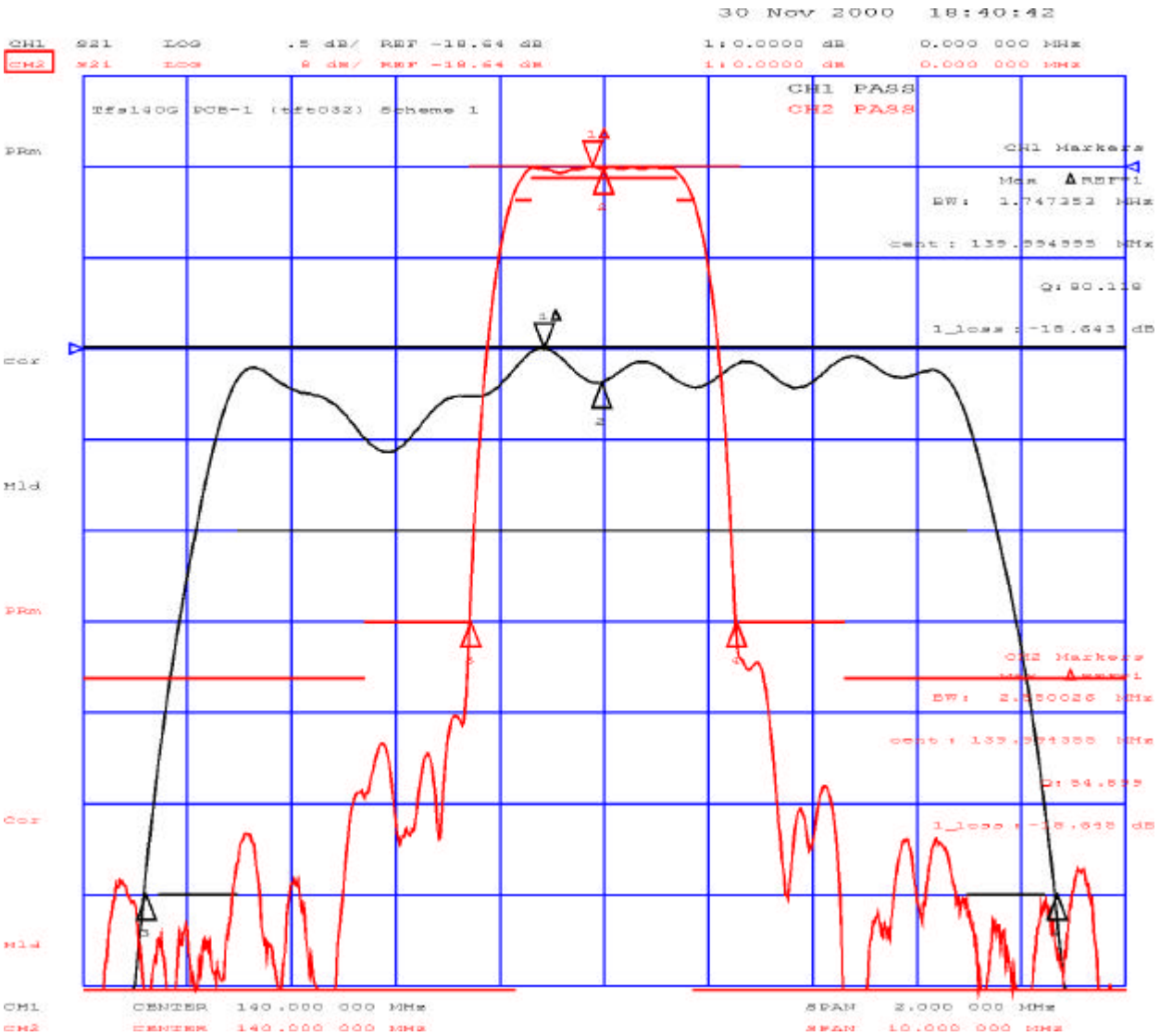
Appendix 1: Measured data of TFS 140G with unbalanced scheme 1.



Scheme 1. PCB –1 (SMD Q = 70)



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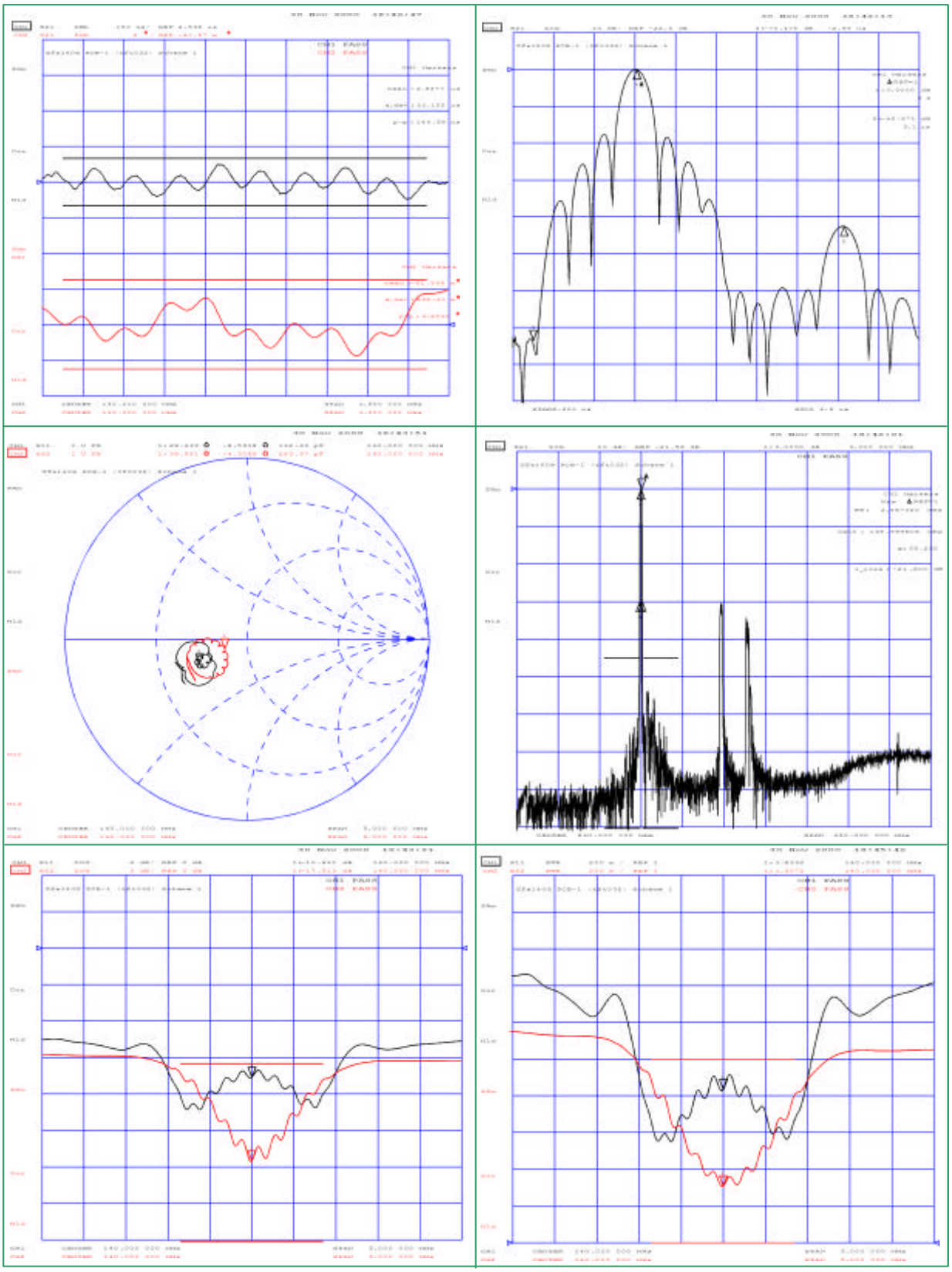

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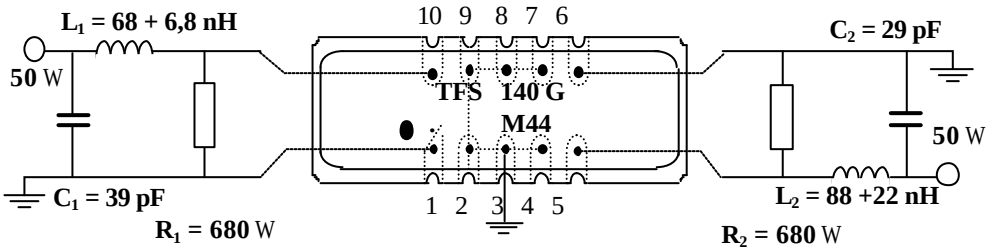
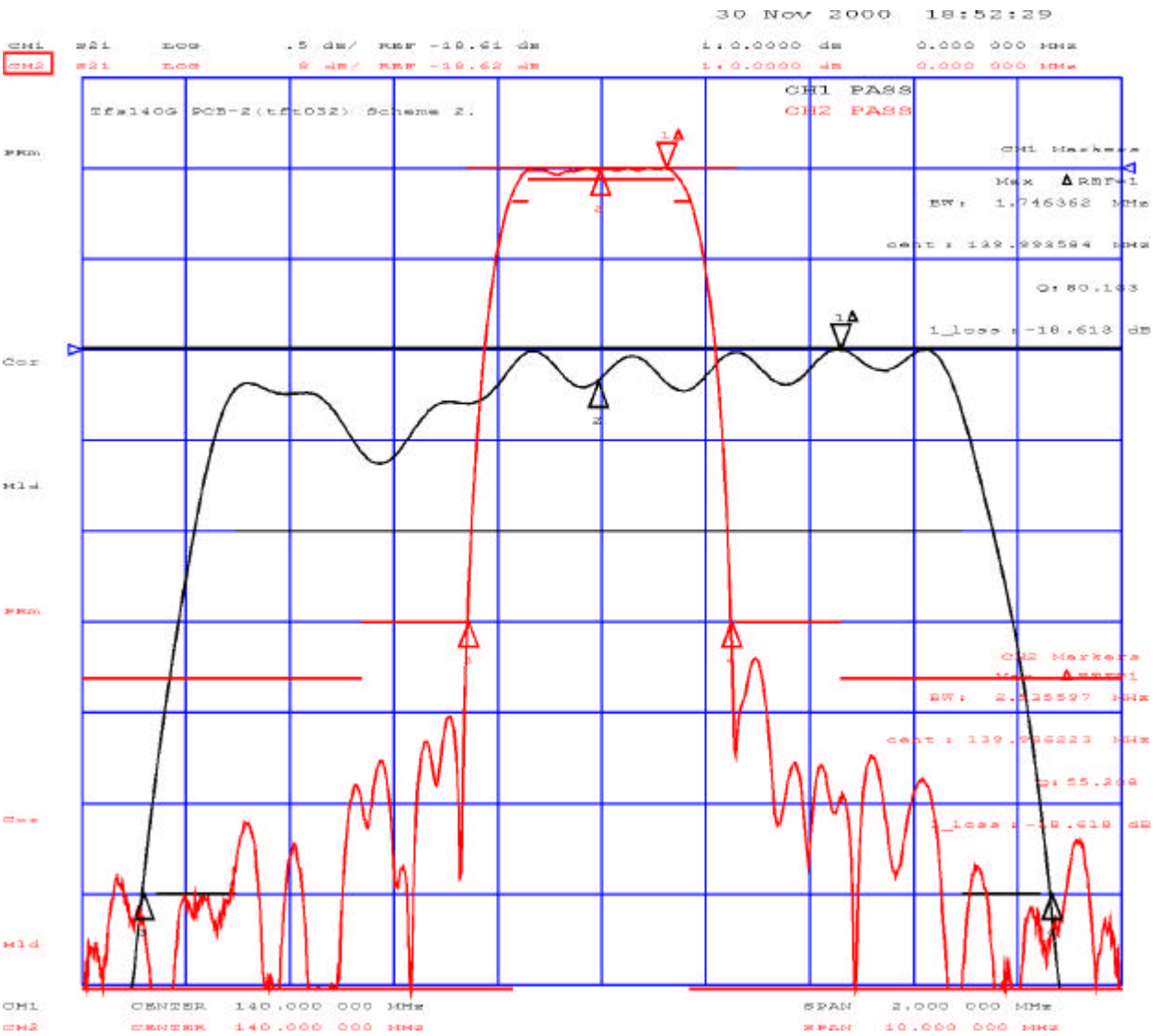
Appendix 2: Measured data of TFS 140G with unbalanced scheme 2.



Scheme 2. PCB-2 (SMD Q = 70)



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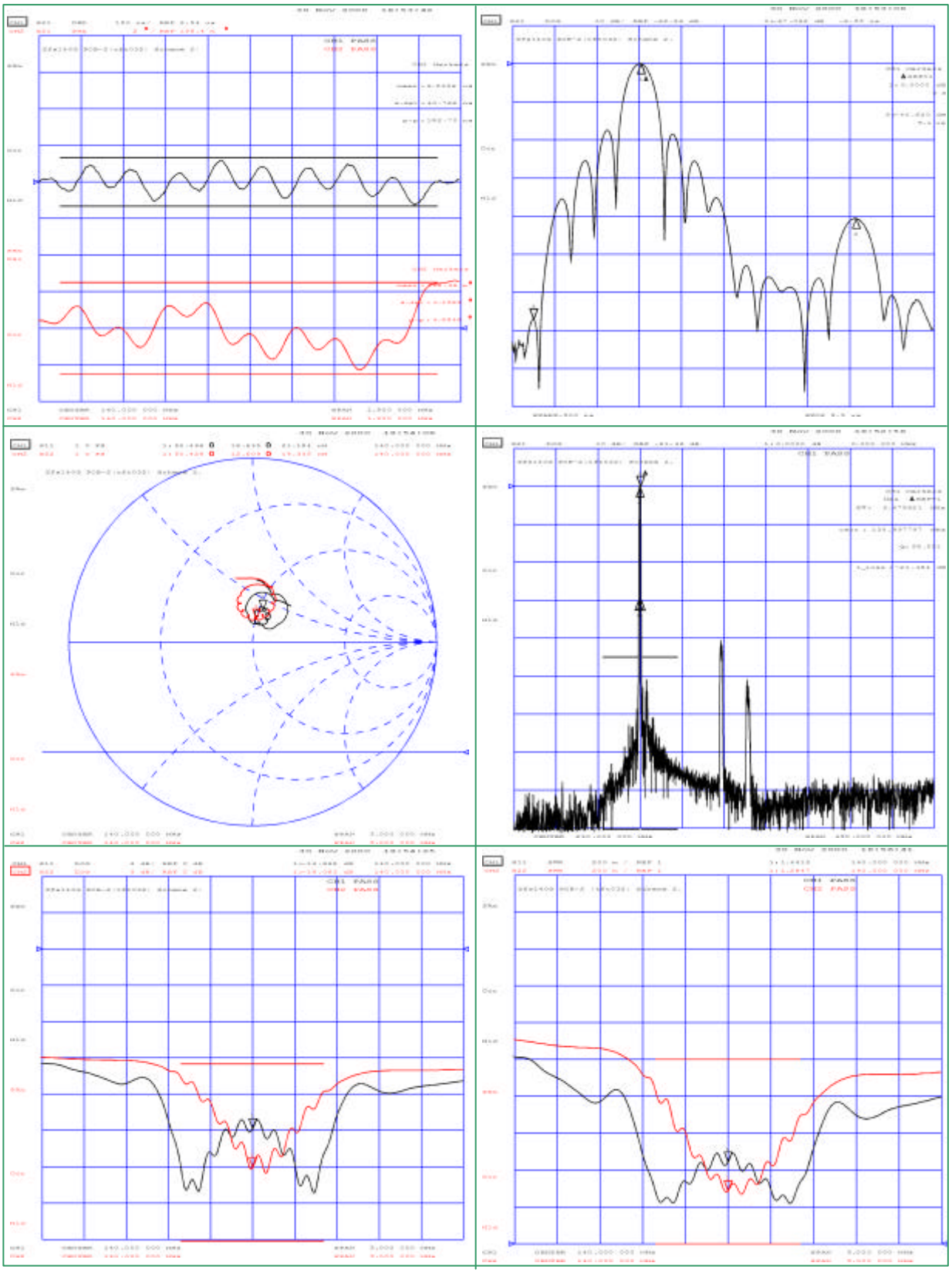
Appendix 2: Measured data of TFS 140G with unbalanced scheme 2.



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