P-bar Note 677

# Equalizers for Accumulator Core Cooling Upgrade

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January, 2003

Six equalizers have been designed and fabricated for accumulator core cooling system (three horizontal bands and three vertical bands.) The specification for these equalizers is: equalize the system between the frequencies where the original transfer function drops to –10 db lower and the insertion loss of the equalizer itself should be less than –3 db at these frequencies (lower/upper edge)

Parallel coupled resonant lines made of stripline structures are used for these equalizers. Most of equalizers use 4 coupled lines except for vertical band 1 which uses 3 coupled lines. Shown in Table 2 are the parameters of the circuits. Tolerance of less than 0.5 mil on line width and separation is needed to achieve or to be close to the designed performance. Each circuit is inspected before and after etching as quality control.

Hewlett Packard ADS (Advanced Design System) software is used for design. The optimization of these equalizers is done manually since manual optimization is much better (and much faster) than the software's optimizer. Standard deviation (STDDEV) divided by Average of the S parameter (real part) of the transfer function is used to "optimize" equalizers' performance. The advantage of using this "criterion" is it gives quantitative description of how "flat" the system is with the equalizer so a designer can quantitatively compare and improve different versions of equalizer designs for a transfer function. However the value of STDDEV/AVERAGE not only depends on the equalizer but also depends on the original transfer function since a equalizer can only change the "general shape" of a transfer function but can not eliminate the "fine" fluctuation or big "local bump" such as a –5 db local drop in Band 3 transfer functions. Therefore this criterion should not be used to compare equalizers' performance for different transfer functions. Shown in Table 1 are measured values of STDDEV/AVEERGAGE of these equalizers. Shown in Figure 1 – 12 are the measured S parameters (in dB or real part) of the transfer function with and without equalizer. The parameters "integ1", "integ2" and "gainadd" in Figure 2-2 – 12-2 are the integration of real part over the designed bandwidth and the extra gain (in dB) needed for the system (with equalizer) to have same output power as the pervious system (without equalizer.) The "measured" STDDEV/AVERAGE values and the S parameters plot of "with equalizer" in Figure 1 - 12 are based on embedded S parameters of original measured transfer function and measured S parameters of equalizers (this means they are measured separately and put together through software.) After these equalizers installed, if the cable length and the phase of the system are adjusted correctly, the new transfer function should be the same as those in Figure 1 – 12. Shown in Figure 13 – 18 are the measured s-parameters (dB and phase) of these filters.

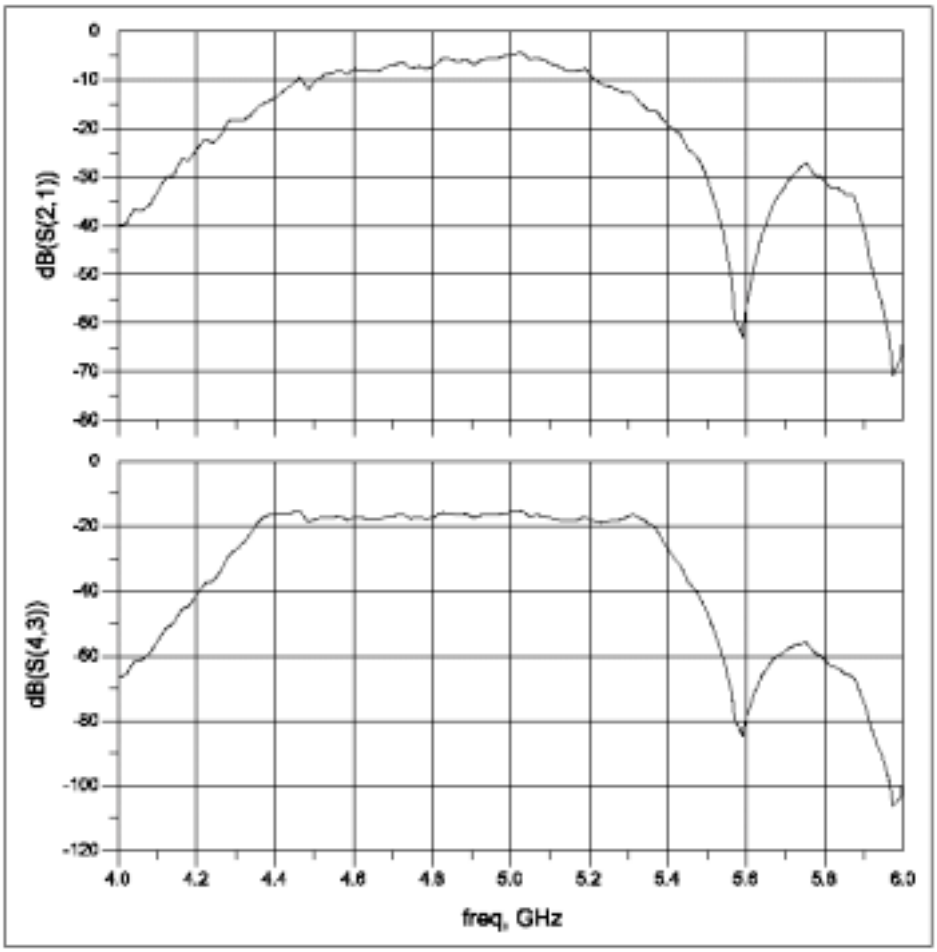



Figure 1. Band1 Horizontal, S parameter (dB) of transfer function
top: without equalizer bottom: with equalizer

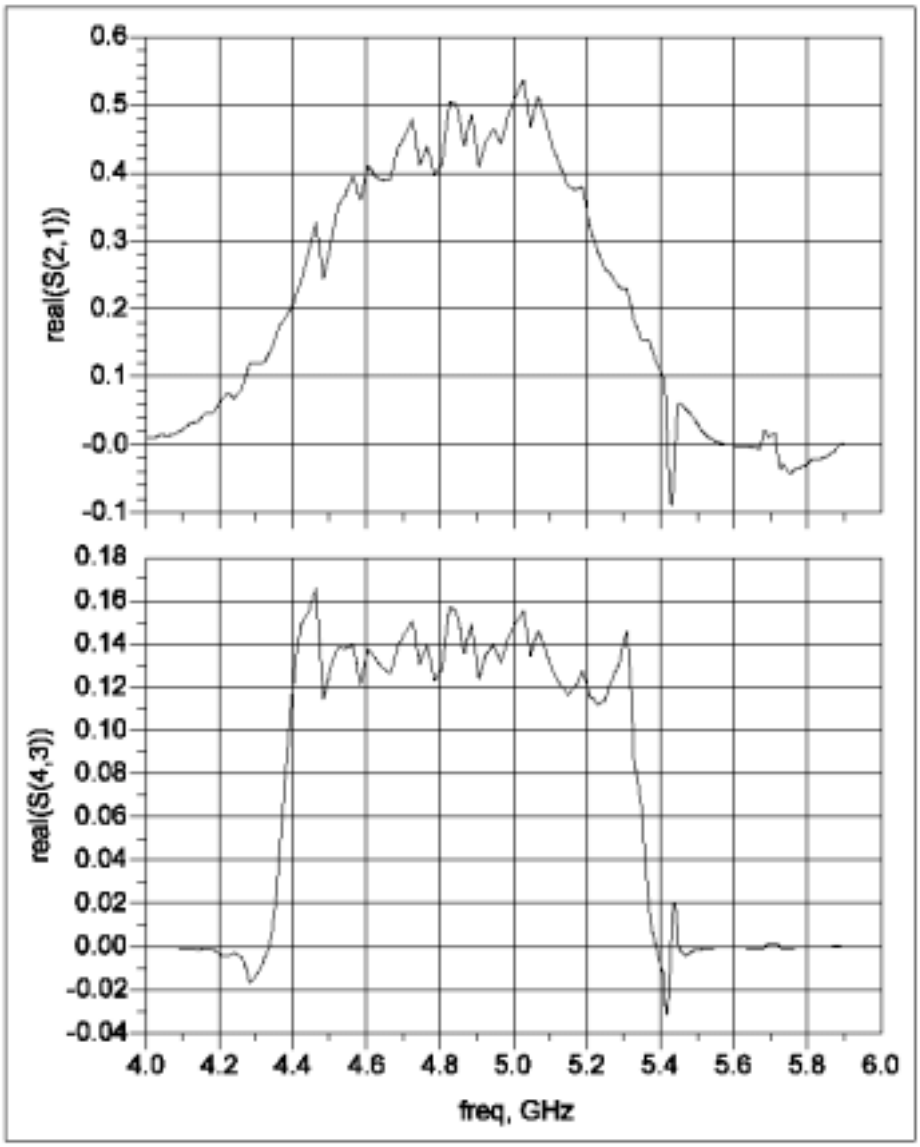
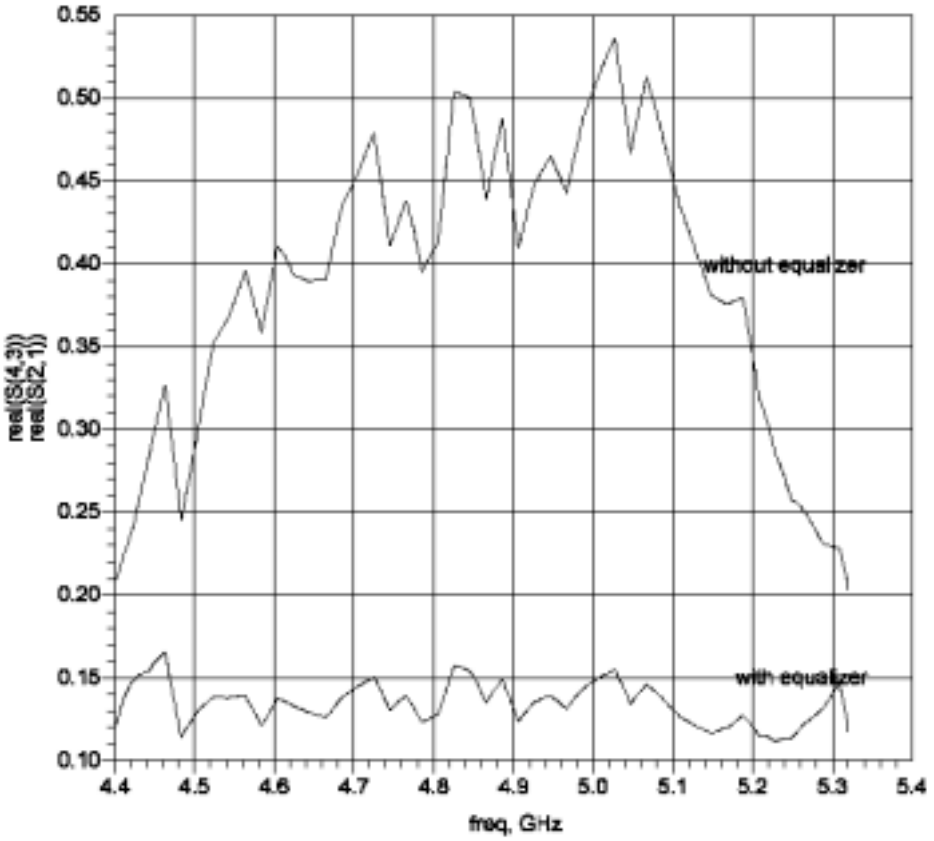



Figure 2. Band1 Horizontal, S parameter (real part) of transfer function
top: without equalizer  bottom: with equalizer




| ave1 | stddev1 | integ1 | ave2 | stddev2 | integ2 | gainadd |
|---|---|---|---|---|---|---|
| 0.391 | 0.065 | 3.598E8 | 0.135 | 0.012 | 1.239E8 | 9.258 |

Figure 2-2. Band1 Horizontal, S parameter (real part) of transfer function with and without equalizer
Ave1, stddev1, integ1: without equalizer
Ave2, stddev2: integ2: with equalizer
Gainadd: 20*log(integ1/integ2)

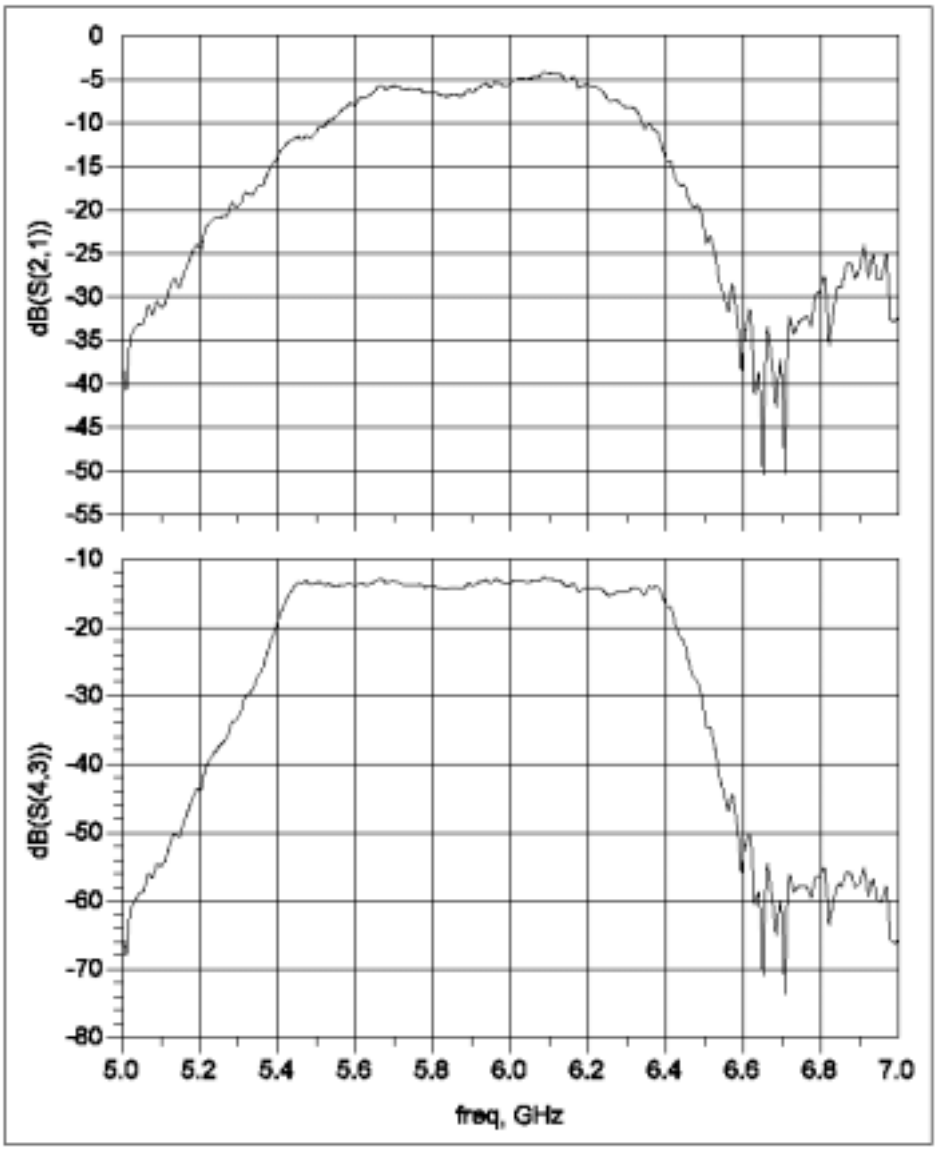



Figure 3. Band 2 Horizontal, S parameter (dB) of transfer function
top: without equalizer  bottom: with equalizer

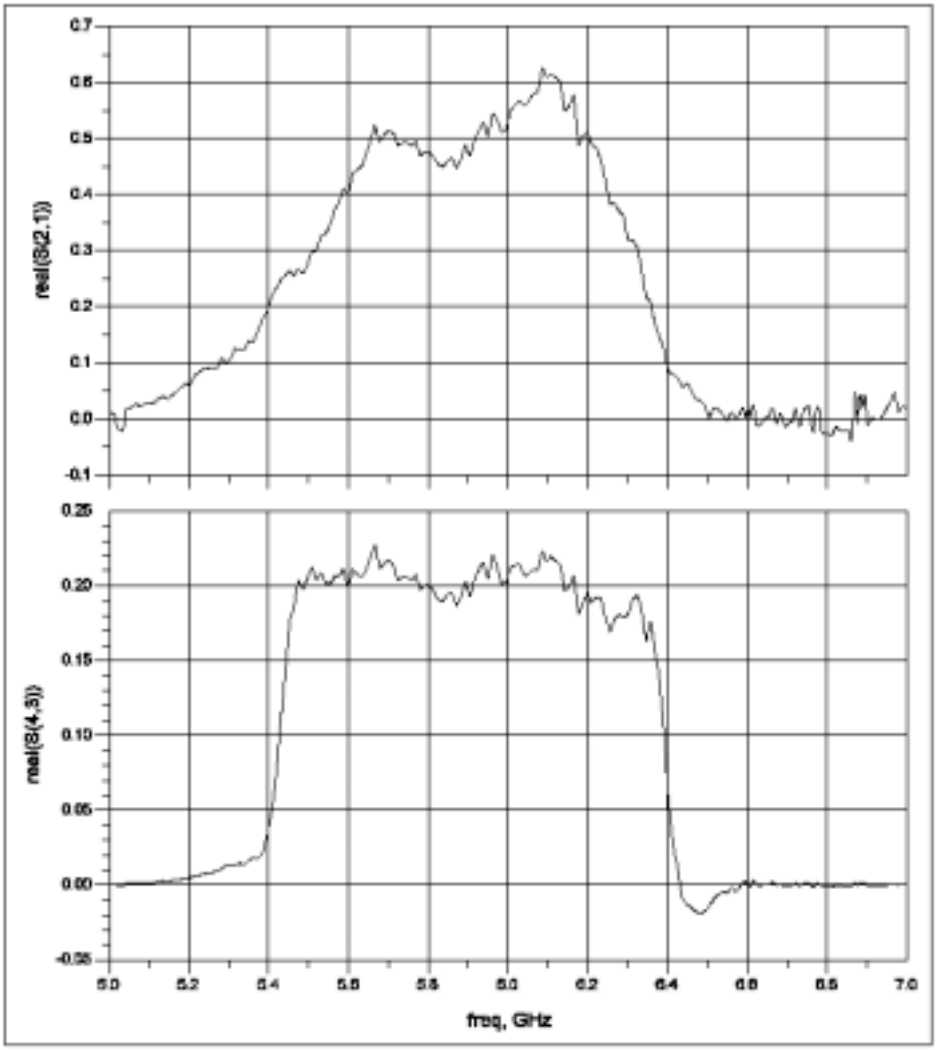
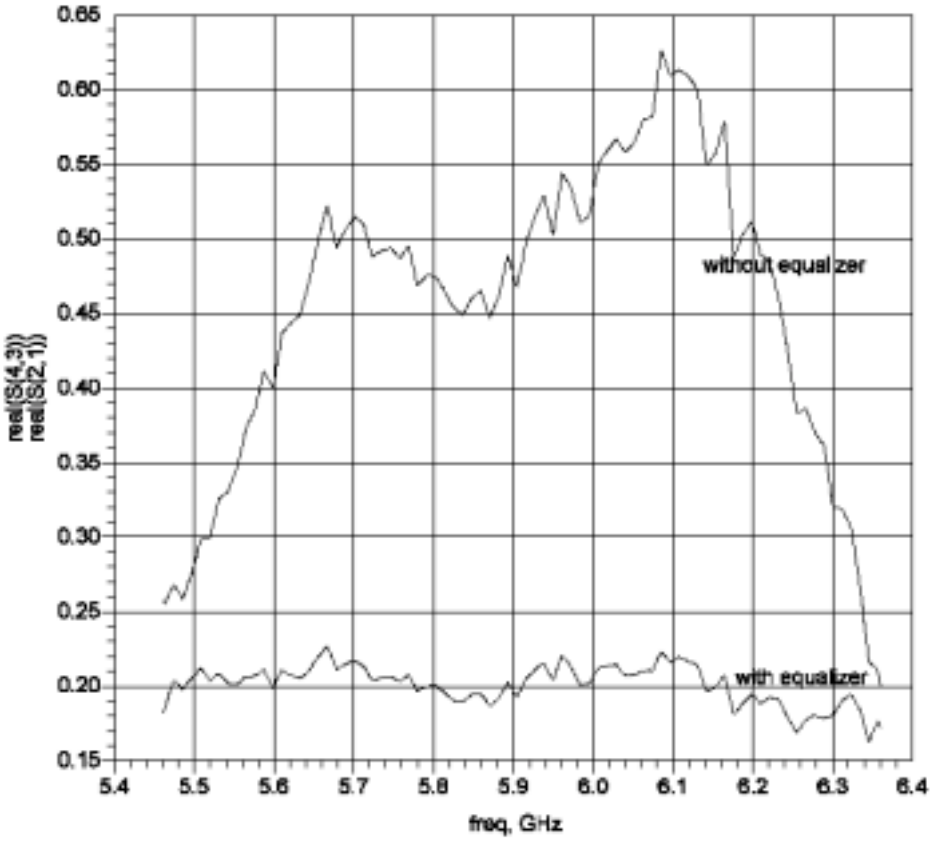



Figure 4. Band 2 Horizontal, S parameter (real part) of transfer function
top: without equalizer  bottom: with equalizer




| ave1 | stddev1 | integ1 | ave2 | stddev2 | integ2 | gainadd |
|---|---|---|---|---|---|---|
| 0.457 | 0.099 | 4.115E8 | 0.201 | 0.012 | 1.812E8 | 7.125 |

Figure 4-2. Band2 Horizontal, S parameter (real part) of transfer function with and without equalizer
Ave1, stddev1, integ1: without equalizer
Ave2, stddev2: integ2: with equalizer
Gainadd: 20*log(integ1/integ2)

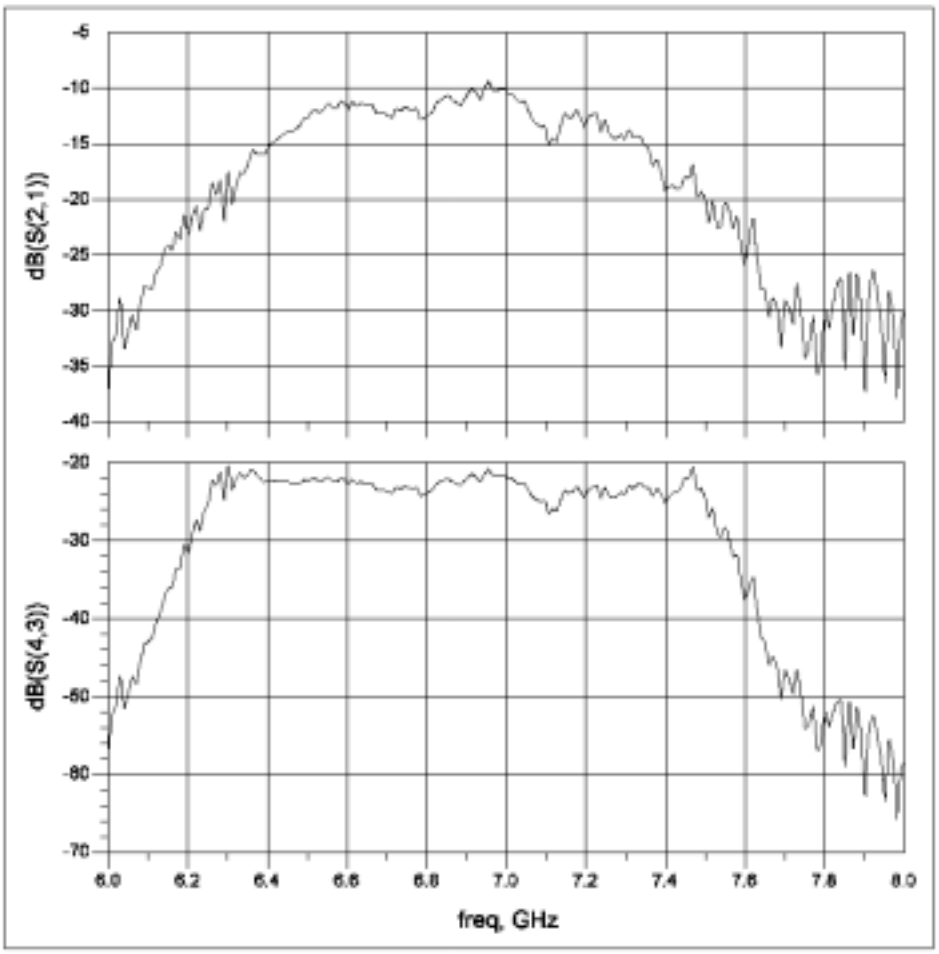



Figure 5. Band3 Horizontal, S parameter (dB) of transfer function
top: without equalizer bottom: with equalizer

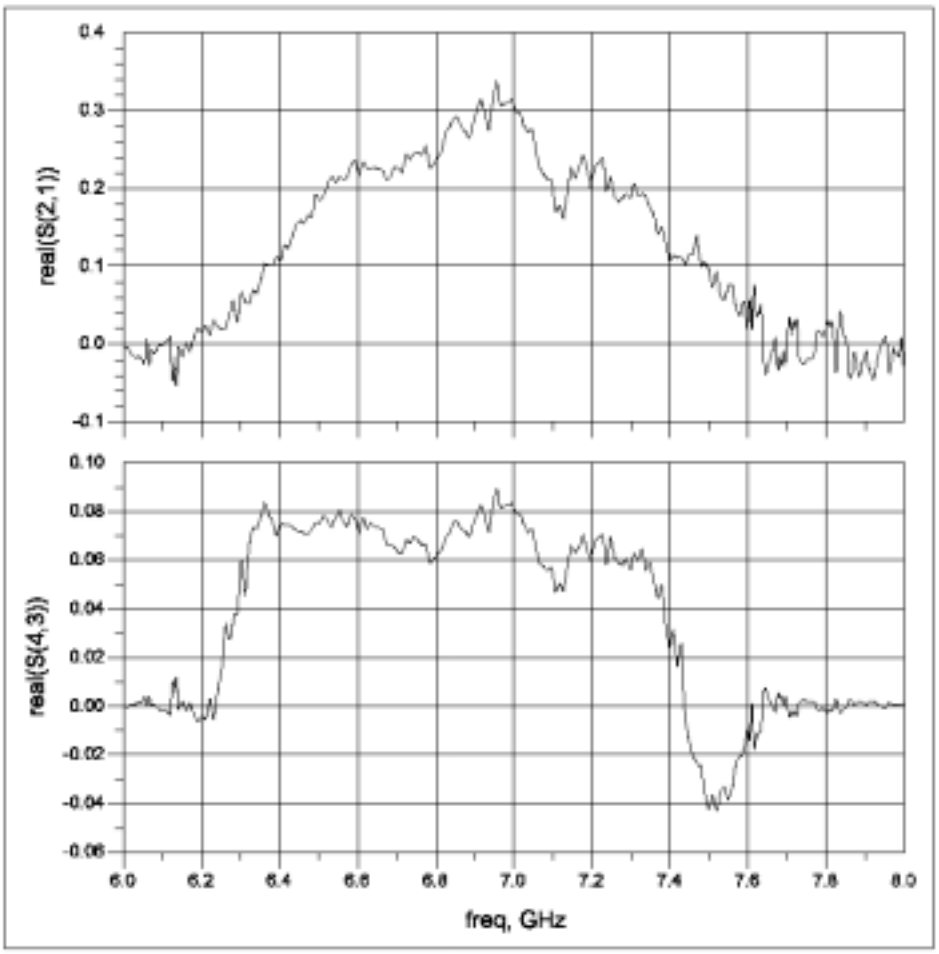
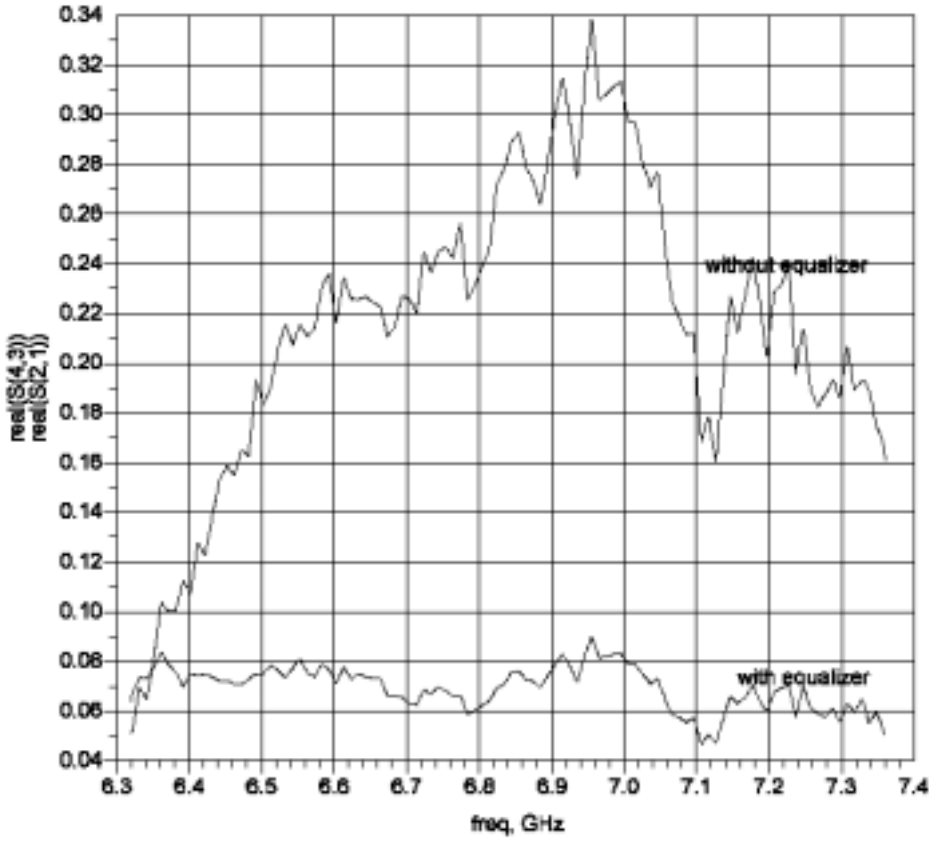



Figure 6. Band3 Horizontal, S parameter (real part) of transfer function
top: without equalizer bottom: with equalizer




| ave1 | stddev1 | integ1 | ave2 | stddev2 | integ2 | gainadd |
|---|---|---|---|---|---|---|
| 0.216 | 0.058 | 2.255E8 | 0.070 | 0.008 | 7.230E7 | 9.879 |

Figure 6-2. Band3 Horizontal, S parameter (real part) of transfer function with and without equalizer
Ave1, stddev1, integ1: without equalizer
Ave2, stddev2: integ2: with equalizer
Gainadd: 20*log(integ1/integ2)

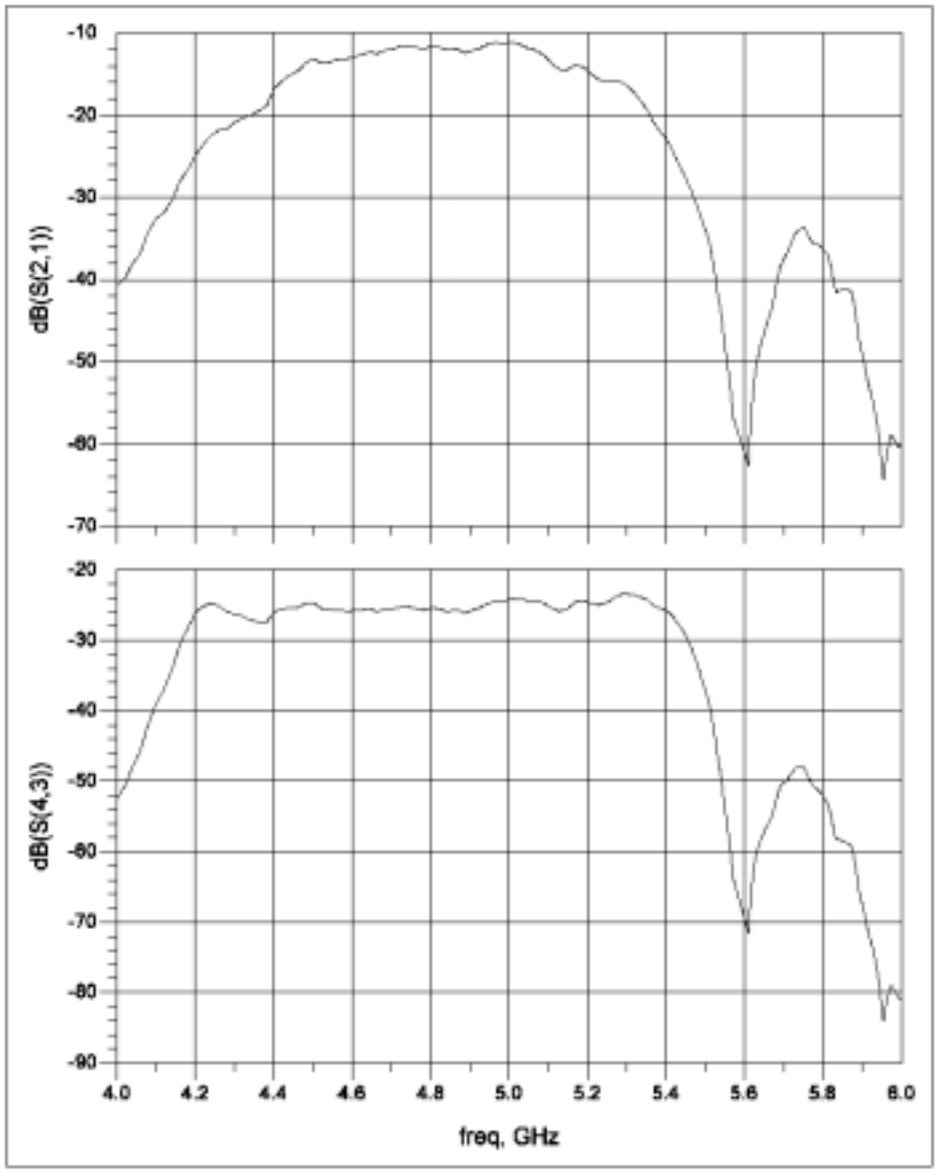



Figure 7. Band1 Vertical, S parameter (dB) of transfer function
top: without equalizer  bottom: with equalizer

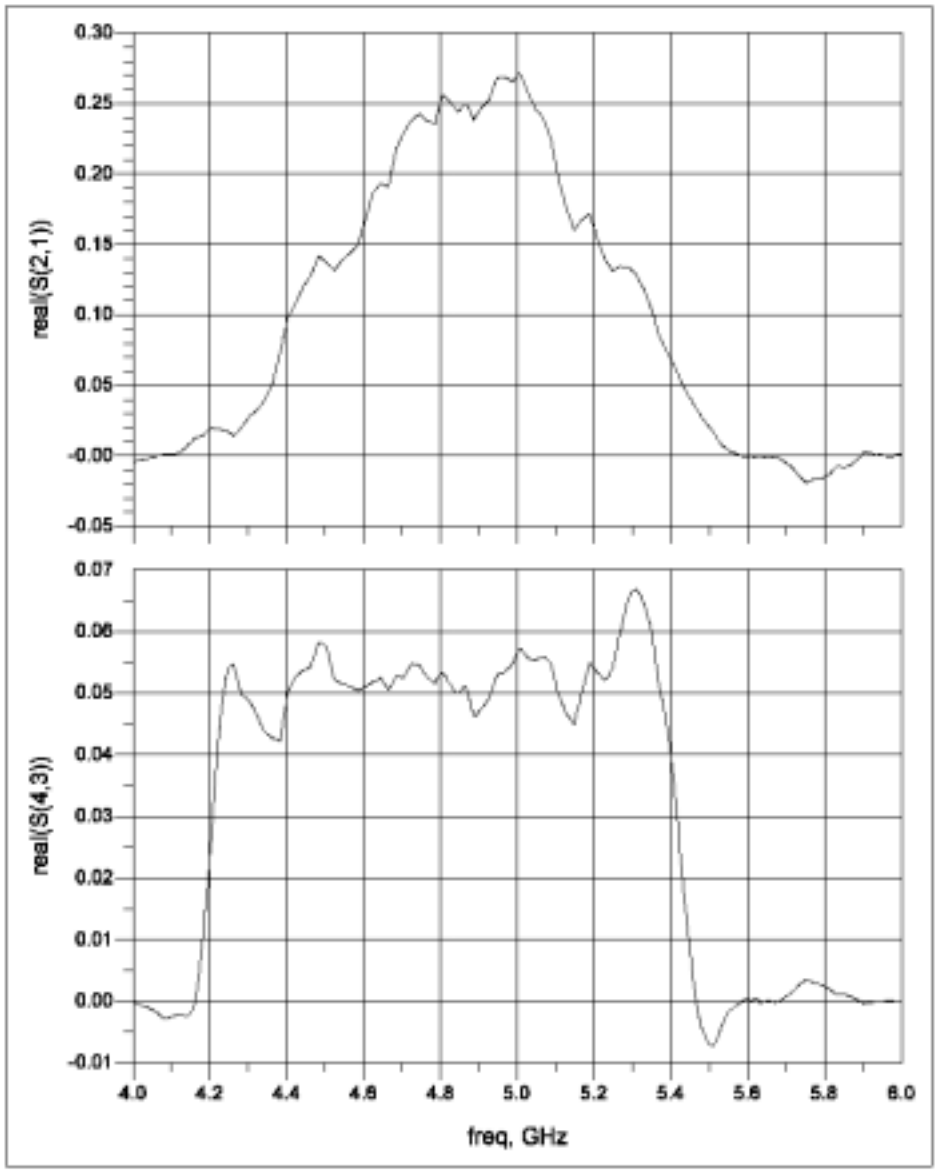
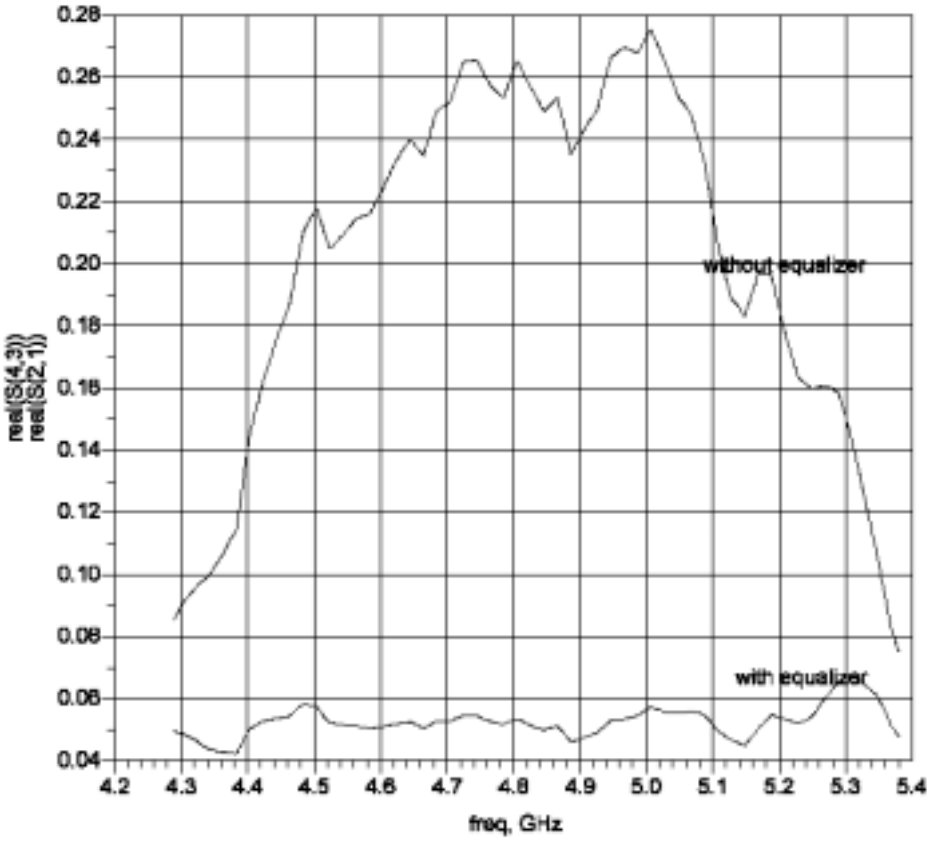



Figure 8. Band1 Vertical, S parameter (real part) of transfer function
top: without equalizer  bottom: with equalizer




| ave1 | stddev1 | integ1 | ave2 | stddev2 | integ2 | gainadd |
|---|---|---|---|---|---|---|
| 0.203 | 0.056 | 2.217E8 | 0.053 | 0.005 | 5.717E7 | 11.772 |

Figure 8-2. Band1 Vertical, S parameter (real part) of transfer function with and without equalizer
Ave1, stddev1, integ1: without equalizer
Ave2, stddev2: integ2: with equalizer
Gainadd: 20*log(integ1/integ2)

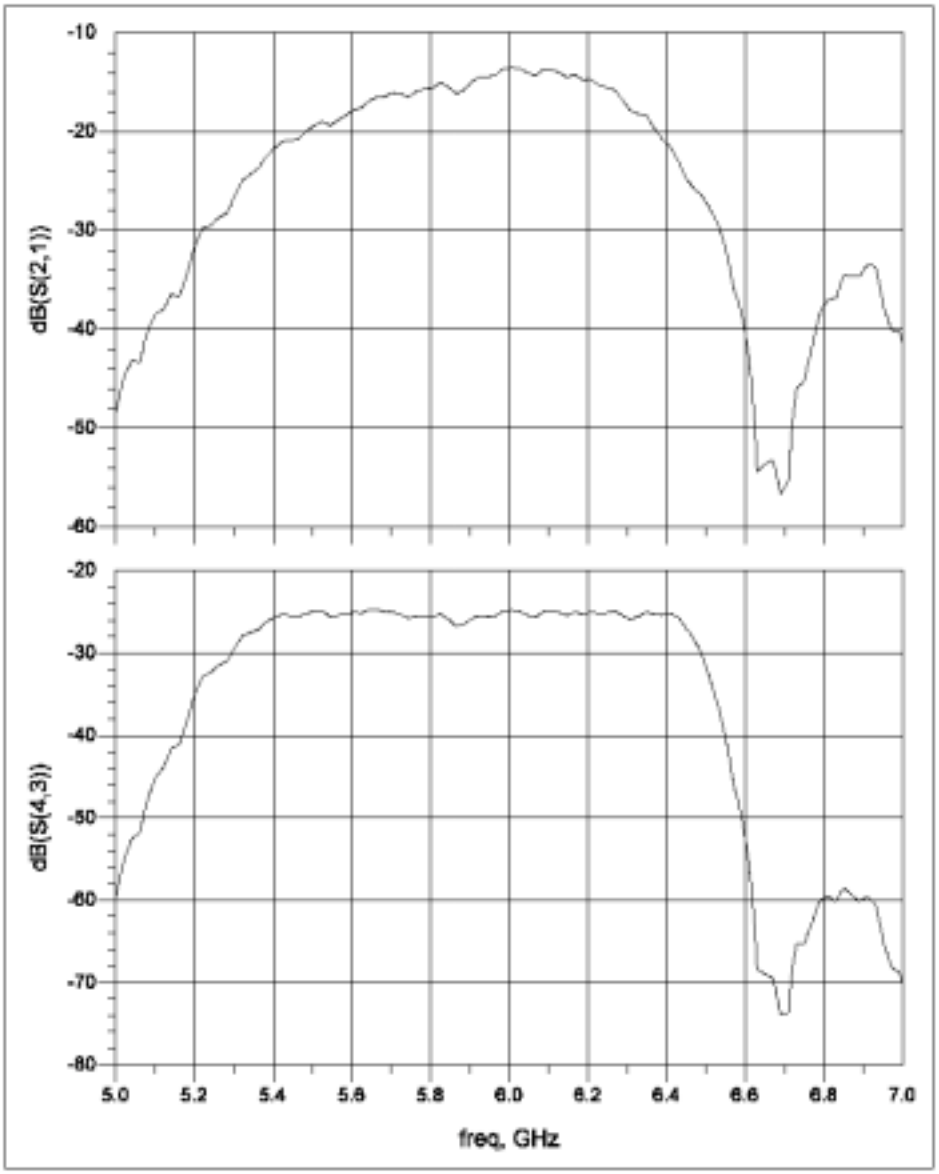



Figure 9. Band2 Vertical, S parameter (dB) of transfer function
top: without equalizer  bottom: with equalizer

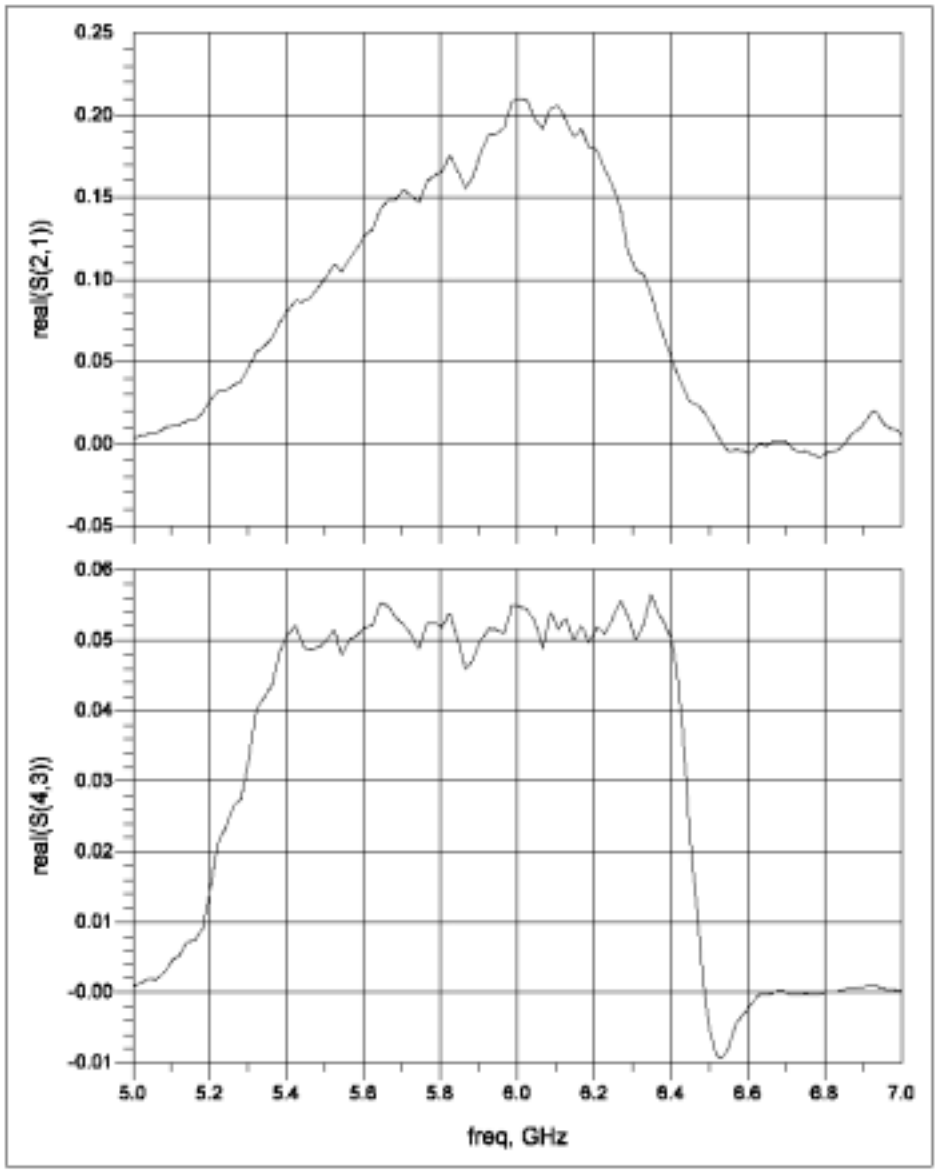
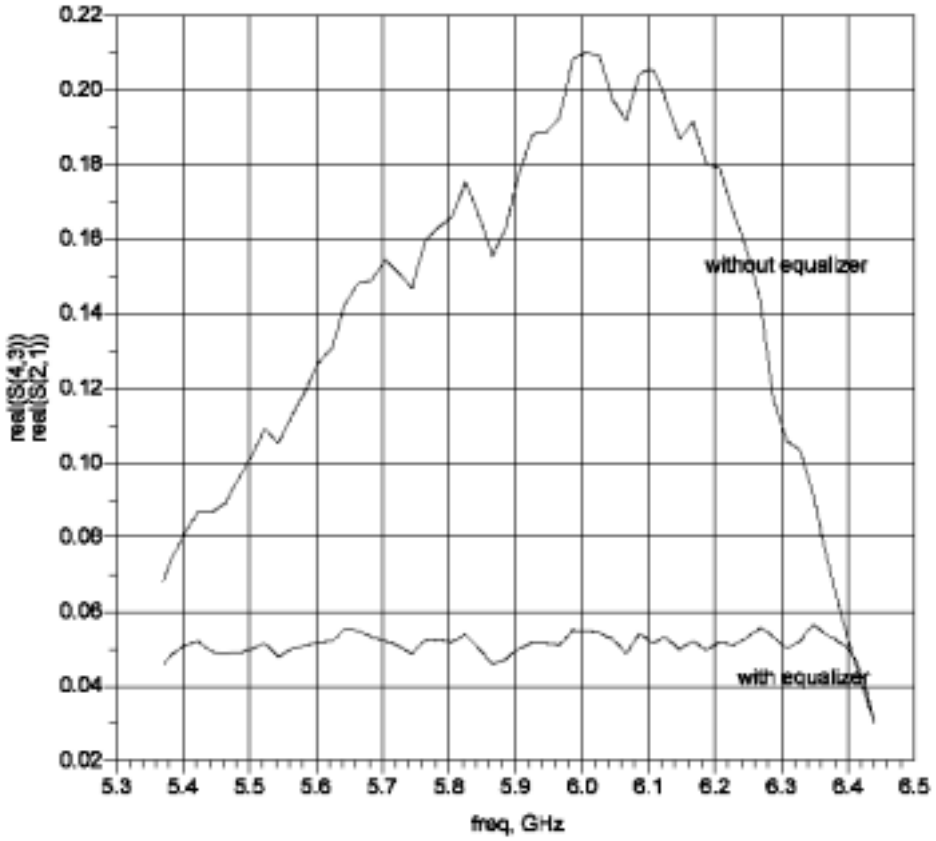



Figure 10. Band2 Vertical, S parameter (real part) of transfer function
top: without equalizer  bottom: with equalizer




| ave1 | stddev1 | integ1 | ave2 | stddev2 | integ2 | gainadd |
|---|---|---|---|---|---|---|
| 0.142 | 0.048 | 1.525E8 | 0.051 | 0.003 | 5.478E7 | 8.891 |

Figure 10-2. Band2 Vertical, S parameter (real part) of transfer function with and without equalizer
Ave1, stddev1, integ1: without equalizer
Ave2, stddev2: integ2: with equalizer
Gainadd: 20*log(integ1/integ2)

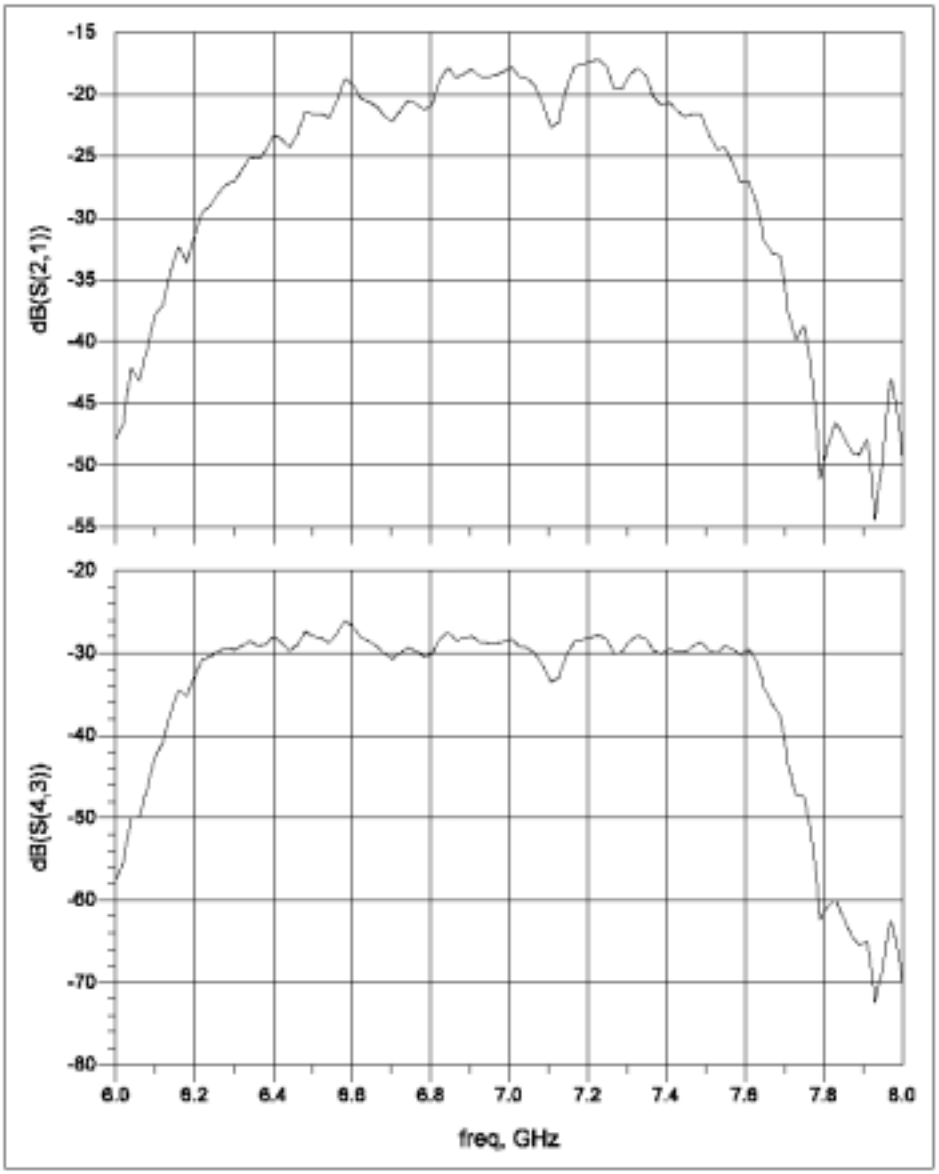



Figure 11. Band3 Vertical, S parameter (dB) of transfer function
top: without equalizer  bottom: with equalizer

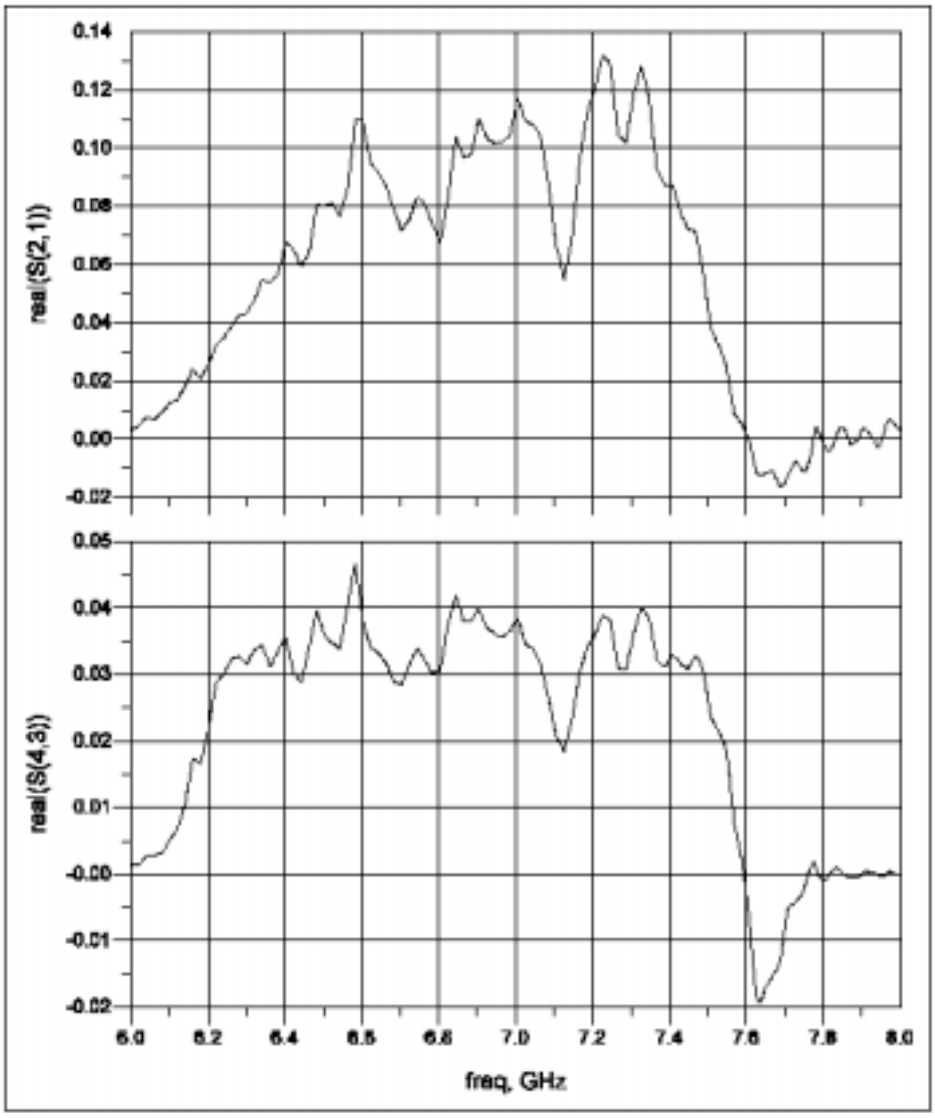
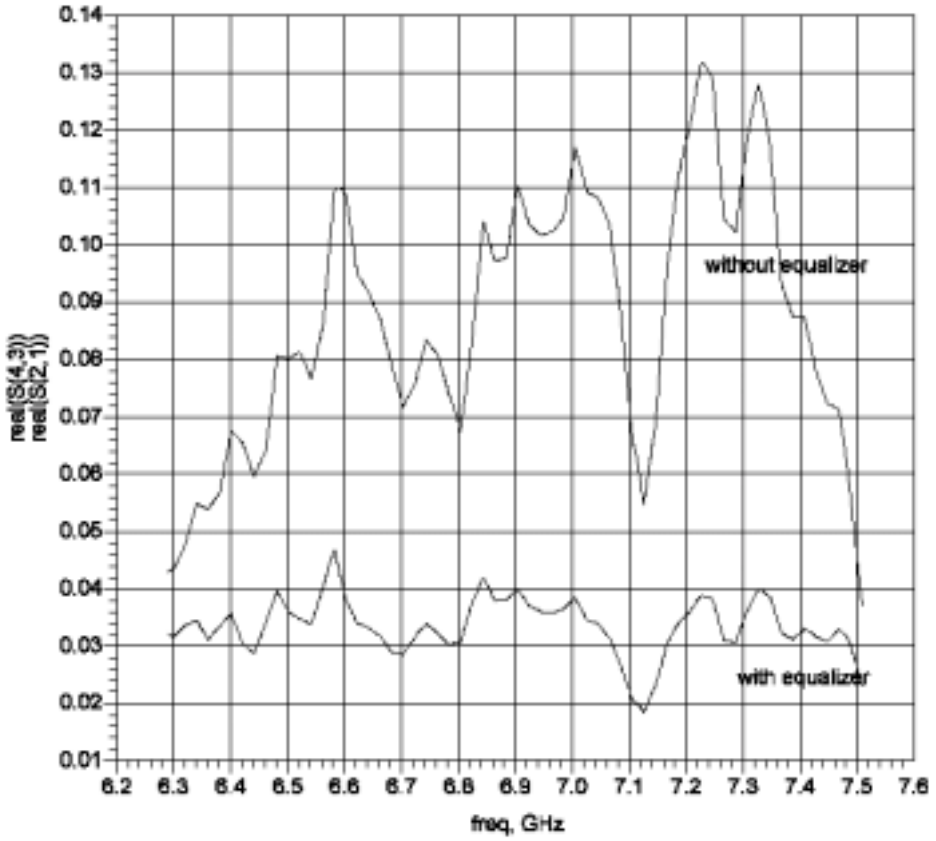



FIgure 12. Band 3 Vertical, S parameter (real part) of transfer function
top: without equalizer  bottom: with equalizer




| ave1 | stddev1 | integ1 | ave2 | stddev2 | integ2 | gainadd |
|---|---|---|---|---|---|---|
| 0.087 | 0.022 | 1.065E8 | 0.034 | 0.005 | 4.098E7 | 8.294 |

Figure 12-2. Band3 Vertical, S parameter (real part) of transfer function with and without equalizer
Ave1, stddev1, integ1: without equalizer
Ave2, stddev2: integ2: with equalizer
Gainadd: 20*log(integ1/integ2)

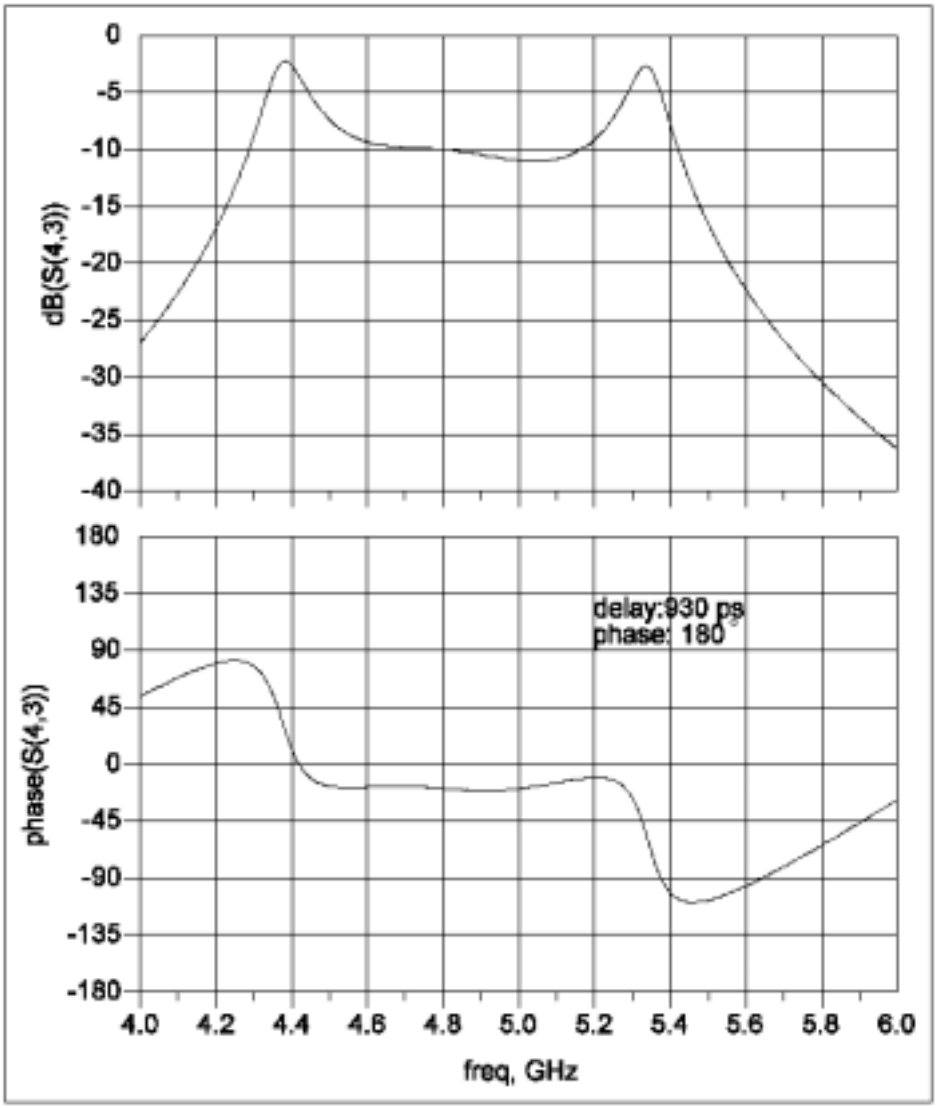



Figure 13. Band 1 Horizontal, S parameter (dB and phase) of equalizer

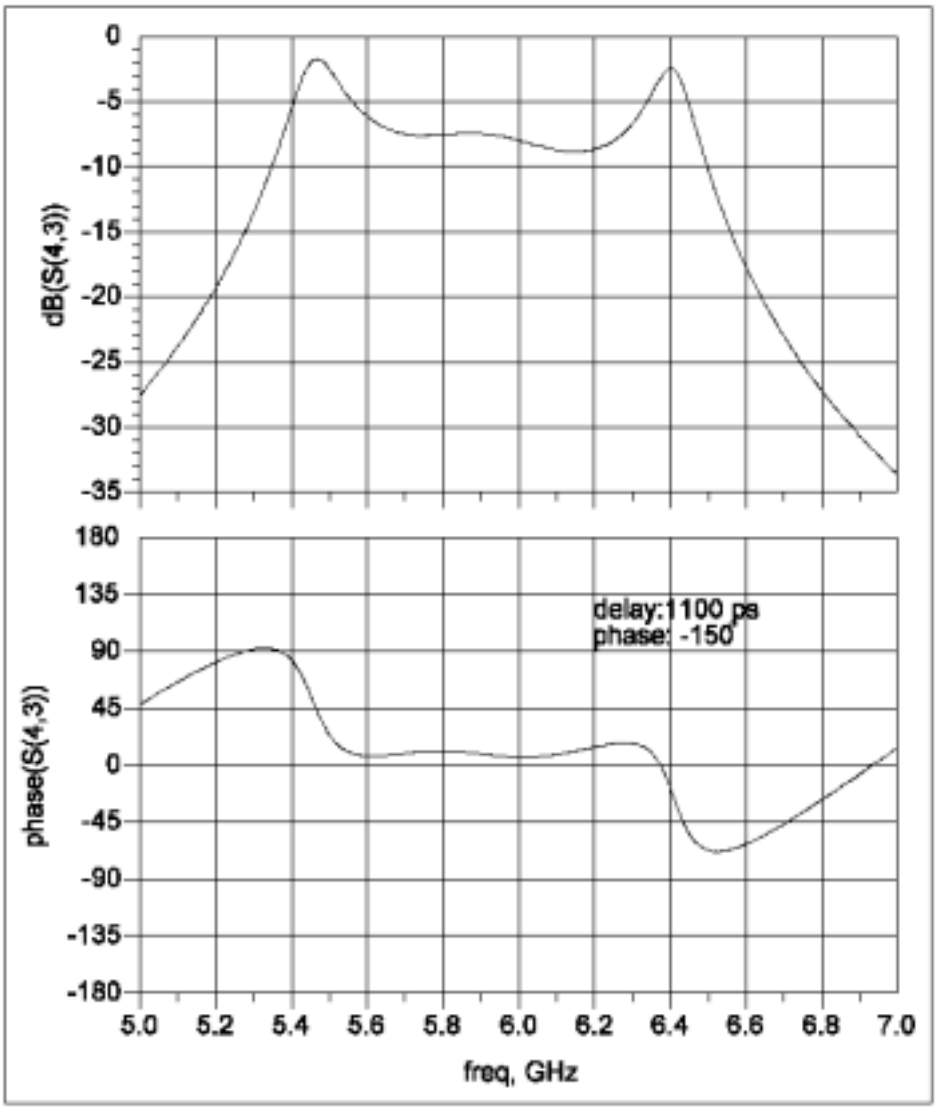



Figure 14. Band 2 Horizontal, S parameter (dB and phase) of equalizer

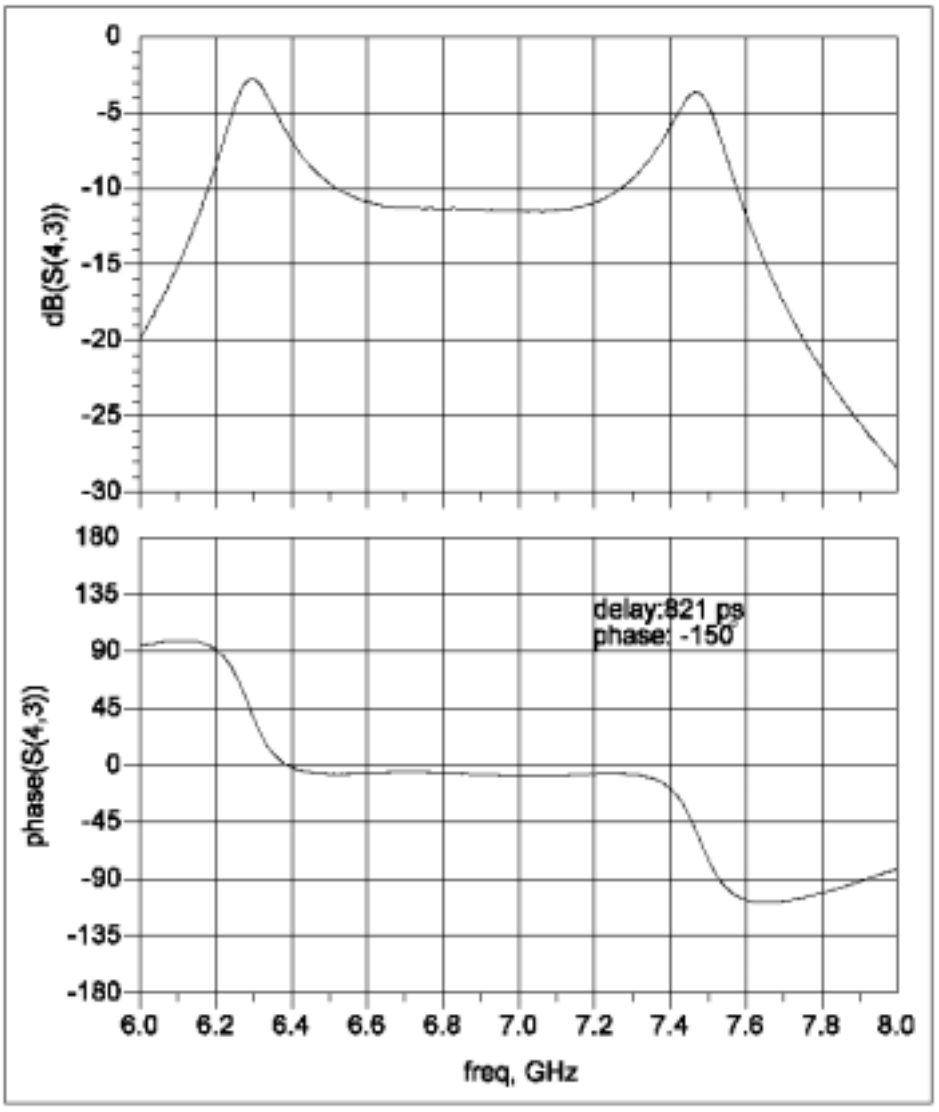



Figure 15. Band 3 Horizontal, S parameter (dB and phase) of equalizer

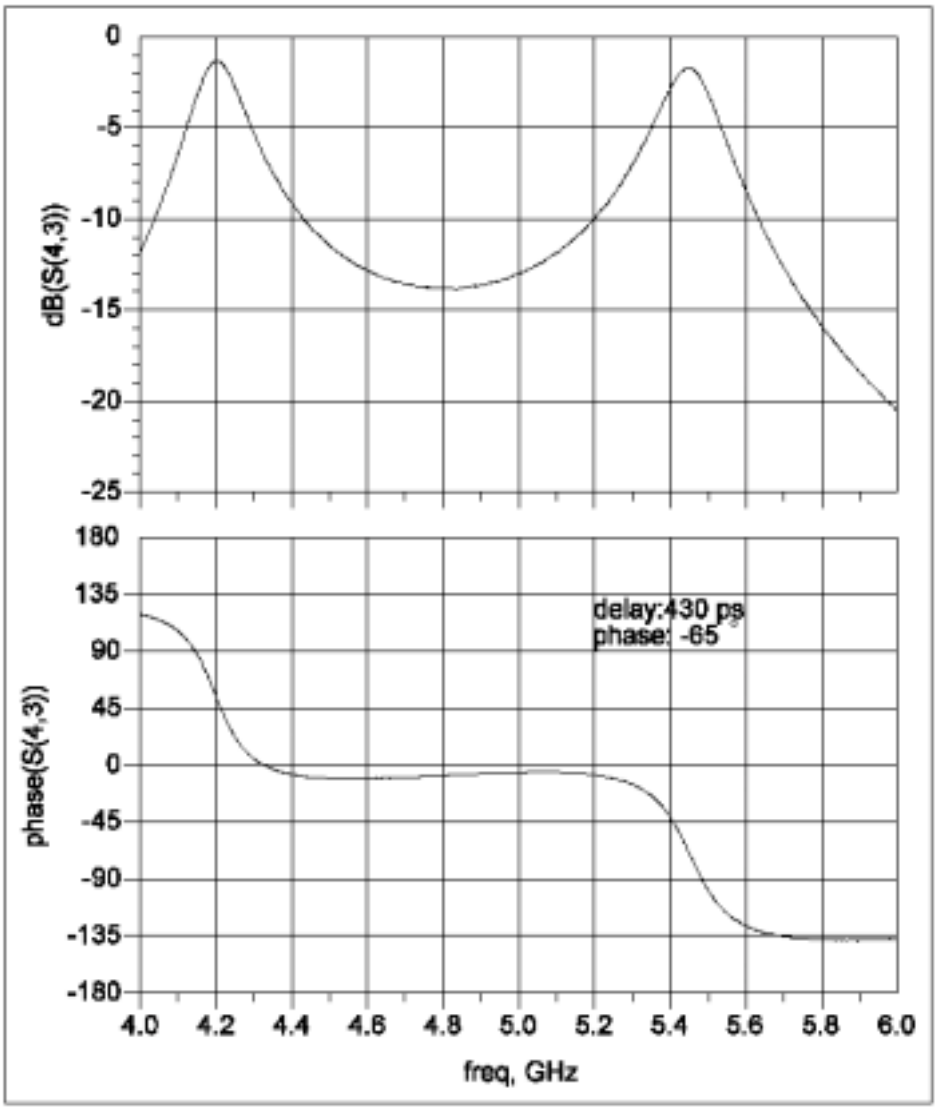



Figure 16. Band 1 Vertical, S parameter (dB and phase) of equalizer

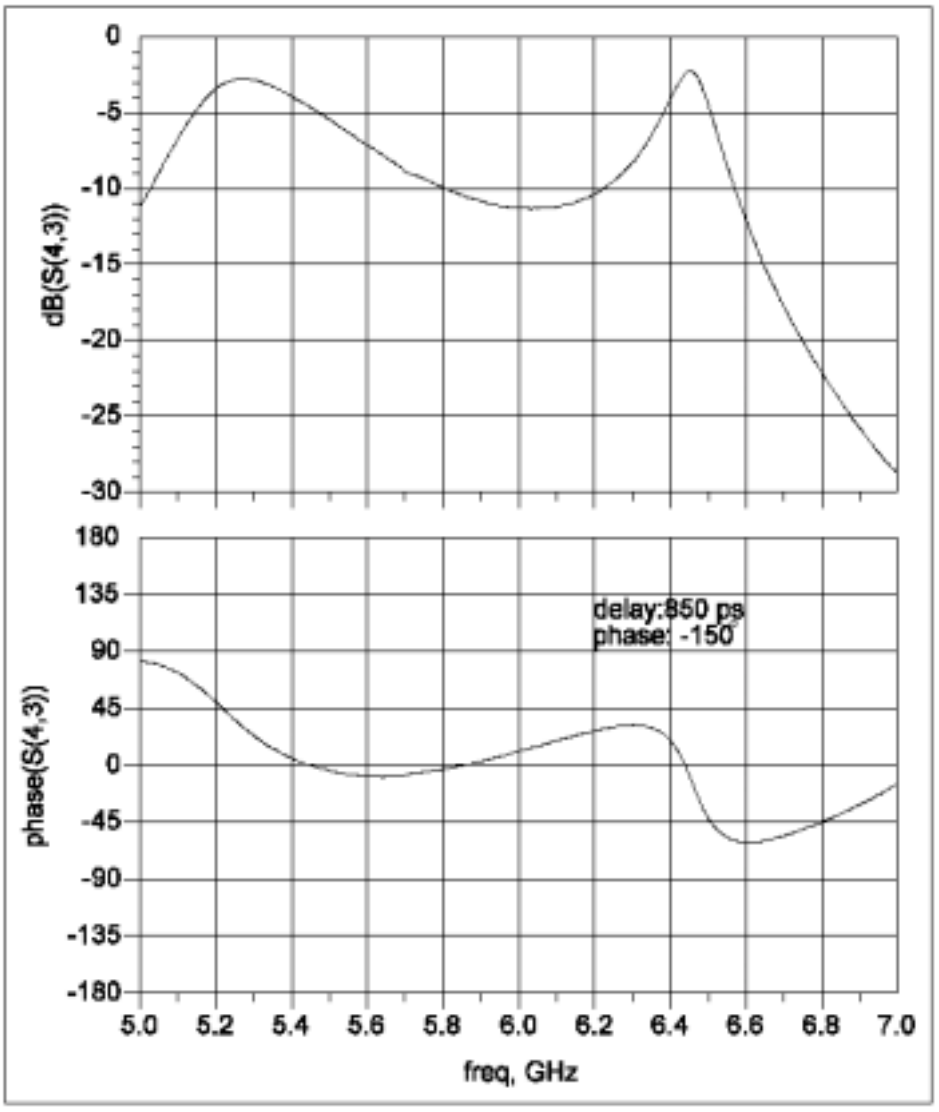



Figure 17. Band 2 Vertical, S parameter (dB and phase) of equalizer

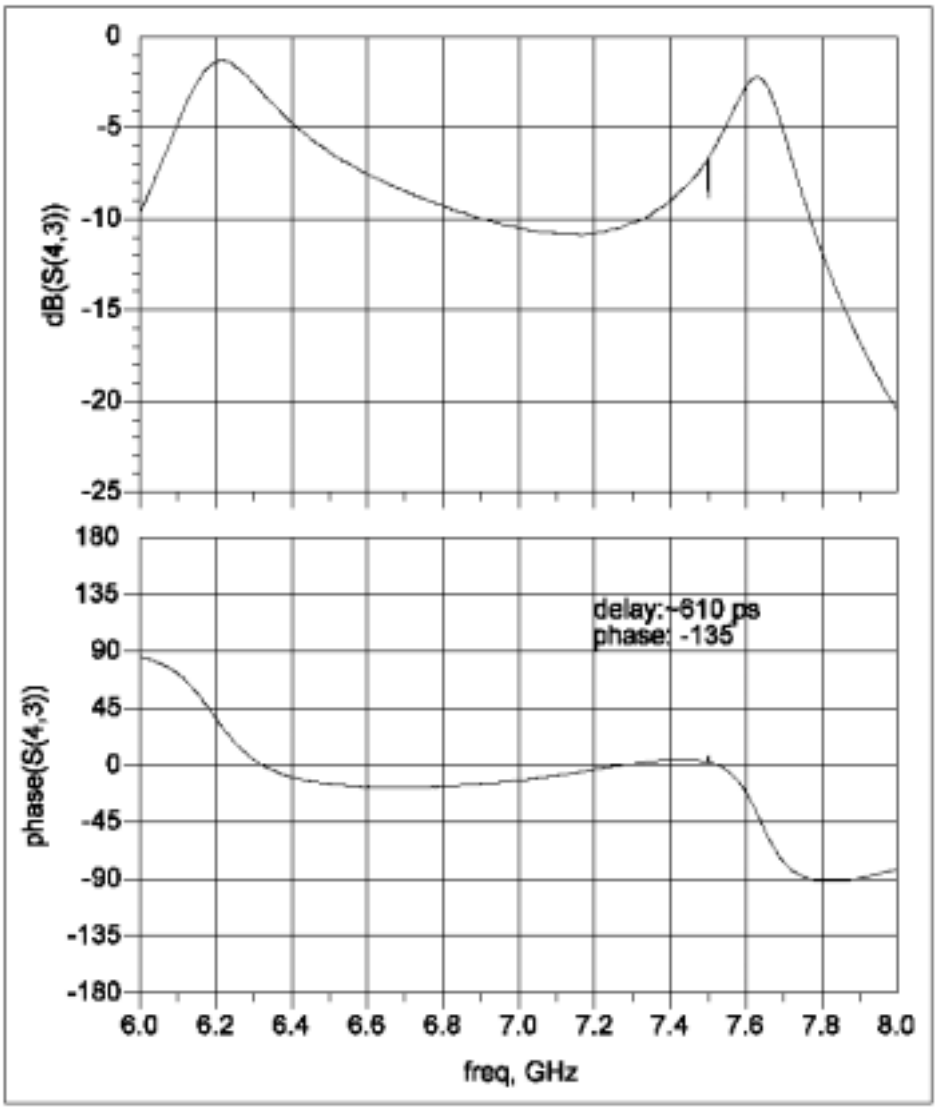



Figure 18. Band 3 Vertical, S parameter (dB and phase) of equalizer

**Table 1. Standard Deviation and Average of S parameter (Real Part)**

| | STDDEV (Standard Deviation) | AVE (Average) | STDDEV/AVE | Frequency Range (GHz) |
|---|---|---|---|---|
| Band 1 H | 0.012 | 0.135 | 8.8% | 4.40 – 5.32 |
| Band 2 H | 0.012 | 0.201 | 6.0% | 5.46 – 6.36 |
| Band 3 H | 0.008 | 0.07 | 11.4% | 6.32 – 7.36 |
| Band 1 V | 0.005 | 0.053 | 9.4% | 4.29 – 5.38 |
| Band 2 V | 0.003 | 0.051 | 5.9% | 5.37 – 6.44 |
| Band 3 V | 0.005 | 0.034 | 14.7% | 6.29 – 7.51 |

**Table 2. Circuit Line Parameters (mil)**

| | W1 | S1 | L1 | W2 | S2 | L2 | W3 | S3 | L3 | W4 | S4 | L4 | W0 | L0 | Edge |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Band1 H | 50.5 | 24 | 359.5 | 48 | 6.8 | 368 | 41 | 29.5 | 380 | 32 | 7 | 371 | 74 | 565 | 15.5 |
| Band2 H | 36 | 28 | 302.0 | 43 | 13 | 295 | 39 | 36 | 300 | 40 | 7 | 301 | 73 | 965 | 15.5 |
| Band3 H | 59 | 27 | 256 | 49 | 11 | 250 | 48 | 26 | 253.5 | 32 | 7 | 254 | 74 | 965 | 15.5 |
| Band1 V | 72 | 6 | 369.5 | 32.5 | 10 | 369.5 | 88 | 6.25 | 369.5 | | | | 74 | 565 | 15.5 |
| Band2 V | 36 | 32 | 300 | 56 | 6.5 | 300 | 94 | 6.5 | 300 | 33 | 7 | 330 | 74 | 565 | 15.5 |
| Band3 V | 38 | 27.5 | 255 | 50 | 8 | 248 | 84 | 12 | 245 | 32 | 7 | 265 | 74 | 565 | 15.5 |

W1: width of coupled line #1
S1: spacing of coupled line #1
L1: length of coupled line #1
W2: width of coupled line #2
S2: spacing of coupled line 2
L2: length of coupled line #2
W3: width of coupled line #3
S3: spacing of coupled line #3
L3: length of coupled line #3
W4: width of coupled line #4
S4: spacing of coupled line #4
L4: length of coupled line #4
W0: width of transmission line
L0: length of transmission line
Edge: extension of coupled lines at each end
Arlon Cuclad 233 45 mil board with permittivity of 2.32 is used for all filters.