DC-20 GHZ N X M Passive Switches

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MMIC switch networks with complexities up to 4 x 4 have been demonstrated using multiple chips, and up to 2 x 2 and 1 x 4 have been demonstrated using single chips. The switches all use a combination of series and shunt passive FET switching elements. A 1 x 2 switch and a 1 x 4 switch are comprised of a single switching stage. A 2 x 2 switch is comprised of two stages of 1 x 2 switches. A 4 x 4 switch is made of four stages of 1 x 2 switches. All the switches are passive and bi-directional, and all operate from dc to 20 GHz.

Introduction

Broadband passive single chip MMIC switches with complexities up to 1 x 2 using a combination of series and shunt FETs have been demonstrated in the past [1][2]. Multiple chip active switches with complexities up to 1 x 4 have also been demonstrated [3]. This paper describes single chip 1 x 2, 2 x 2, and 1 x 4 switches, and a 4 x 4 switch made up of four 2 x 2 switches.

The schematic of the 1 x 2 switch is shown in Figure 1. This is a conventional broadband circuit using a combination of series and shunt switching FETs. The FETs are all passive, with a resistive "on" state and a capacitive "off" state. Gate bias is used to control the devices. The switch operates from dc to a high frequency cut-off. Unlike active or passive switches using signal splitters (such as a Wilkinson), there is no inherent 3 dB loss per 1 x 2 switch stage in this type of design.

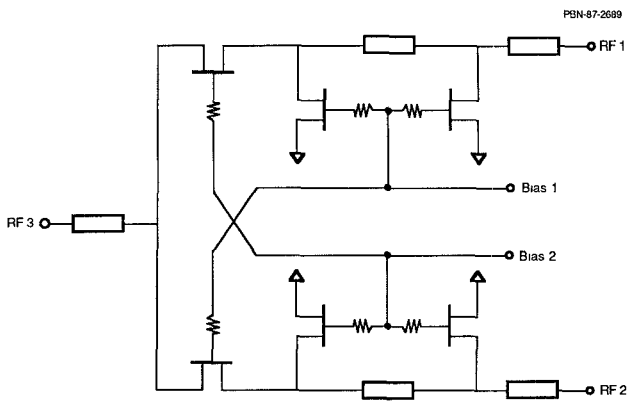

Figure 1. 1x2 MMIC Switch Schematic.

The 1 x 4 switch uses a structure similar to the 1 x 2 switch, as is seen in Figure 2. Four series FETs are connected to the "RF5" node, followed by four shunt FET arms. The 2 x 2 switch consists of four 1 x 2 switches, as is shown in Figure 3. Note that with this switch configuration two signals can be passed simultaneously between two different sets of ports. A 4 x 4 switch can similarly be made up of four 2 x 2 switches, and is described below.

Circuit Results

The 1 x 2, 2 x 2, and 1 x 4 switches were all fabricated as single chip MMICs. Ion implantation was used to realize an active layer carrier concentration of 1.8 x 10^{17} cm^{-3}. The gate length is 0.5 micron. All resistors are 2 kohm and are made with multiple open gate FETs.

The complete 1 x 2 MMIC is shown in Figure 4. The performance for this circuit is shown in Figure 5. Insertion

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loss is less than 2 dB to 20 GHz, isolation is better than 30 dB, and return loss is better than 10 dB.

The complete 1 x 4 MMIC is shown in Figure 6. The performance of this circuit is shown in Figures 7 and 8. Figure 7 shows the insertion loss and return loss for one arm, the other three are very similar. Insertion loss is better than 2 dB to 15 GHz, and better than 4 dB to 22 GHz. Return loss is better than 10 dB to 15 GHz, but has peaks to 6 dB between 15 and 20 GHz. Figure 8 shows representative isolations. Isolation is dependent on the rf path, but is better than 30 dB to 20 GHz between any two rf ports. When a signal is passed between rf ports 5 and 2, isolation is better than 30 dB at port 3 and better than 38 dB to ports 1 and 4. The performance of the single stage 1 x 4 switch is equivalent to what is expected of 2 stages of 1 x 2 switches, but with much less circuit complexity, and a far smaller chip size.

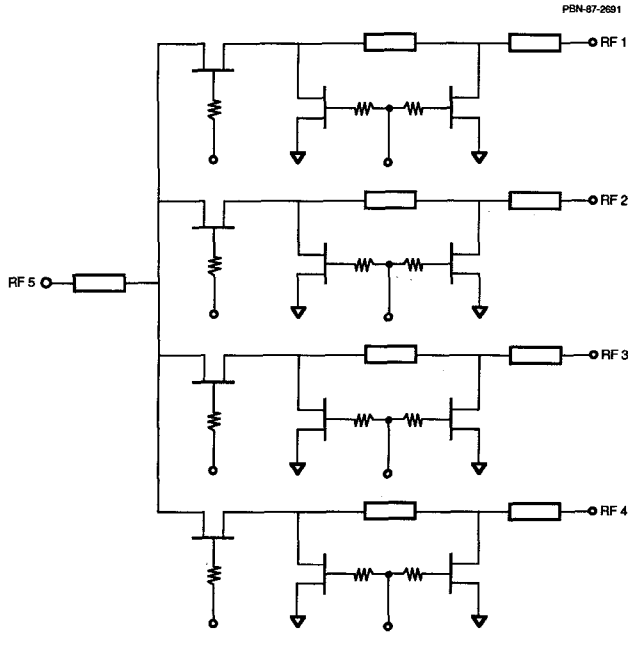

Figure 2. 1x4 MMIC Switch Schematic.

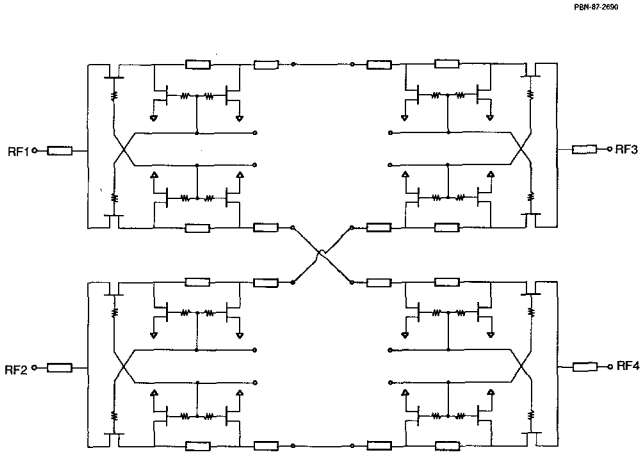

Figure 3. 2x2 MMIC Switch Schematic.

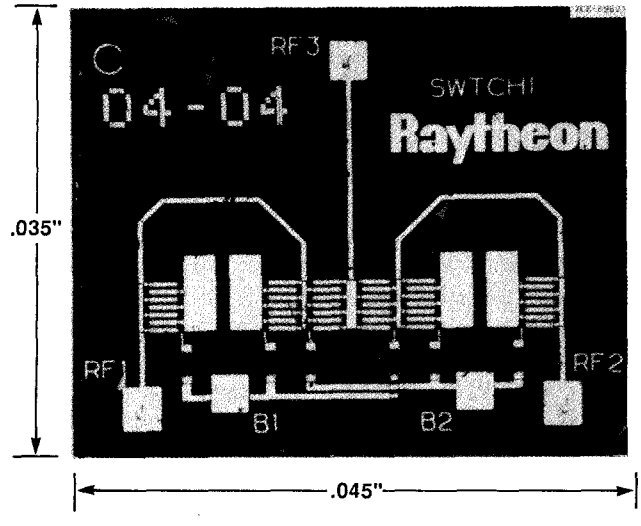

Figure 4. Photograph of 1 x 2 MMIC Switch (35 x 45 mils).

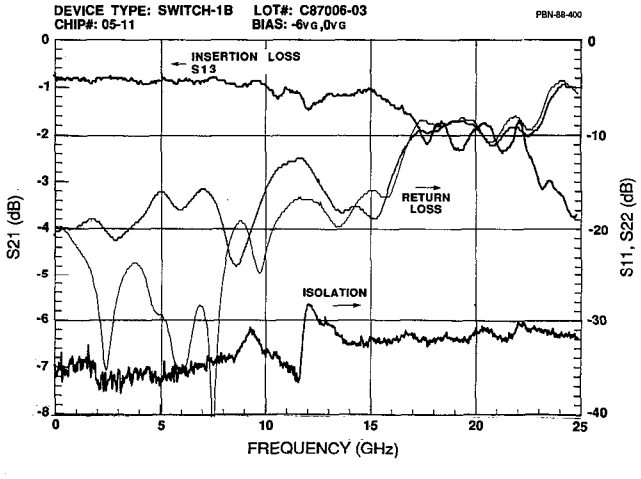

Figure 5. Performance of the 1 x 2 Switch.

The complete 2 x 2 MMIC is shown in Figure 9. The performance of this circuit is indicated is Figures 10 and 11. Insertion loss is less than 3.5 dB to 20 GHz, and return loss is better than 10 dB. There are two sets of measured isolations. When signals are not passed through the central cross-over (from RF1 to RF3 or from RF2 to RF4), the isolation is better than 30 dB to 20 GHz. When signals are passed through the cross-over (RF1 to RF4 or RF2 to RF3), isolation degrades 25 dB. The isolation is degraded by coupling across the cross-over. The line width at the cross-over is 70 microns. These lines have been reduced in width to 10 microns, and measured isolations have been improved to greater than 30 dB.

A 4 x 4 switch has been assembled of four 2 x 2 MMICs, and is shown in Figure 12. The performance for this switch is shown in Figures 13, 14 and 15. As is expected, the performance is very closely related to the 2 x 2 switch's performance. Insertion loss for all 16 possible signal paths is shown in Figure 13. The loss is

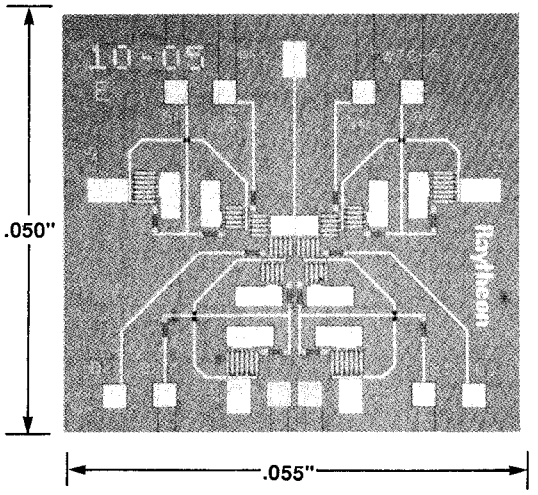

Figure 6. Photograph of 1 x 4 MMIC Switch (50 x 55 mils).

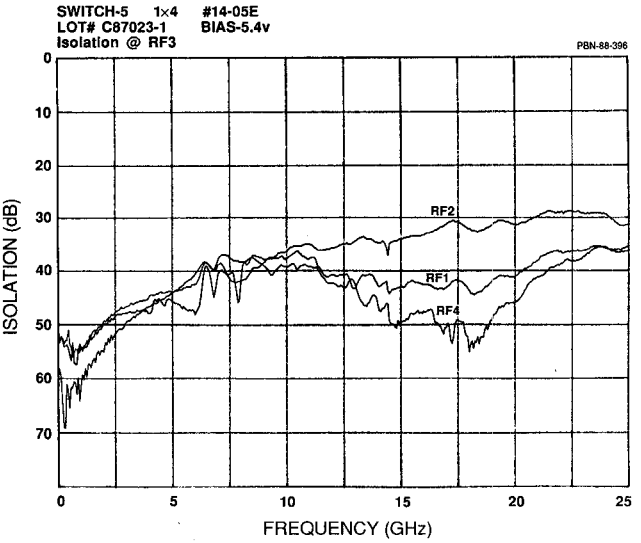

Figure 8. Isolation of the 1 x 4 Switch.

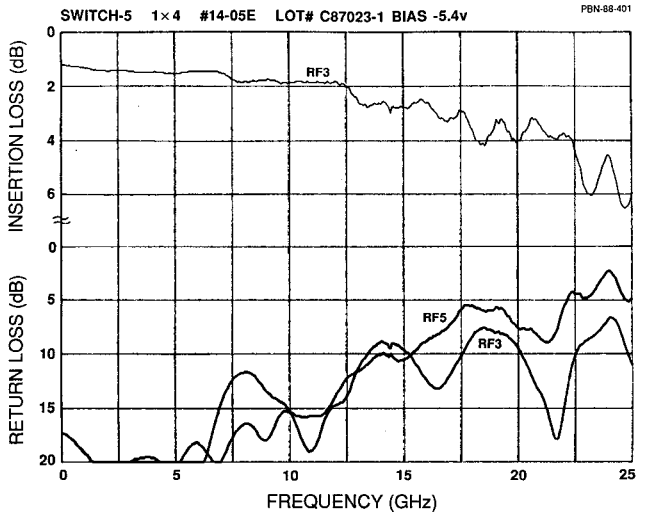

Figure 7. Insertion Loss and Return Loss of the 1 x 4 Switch.

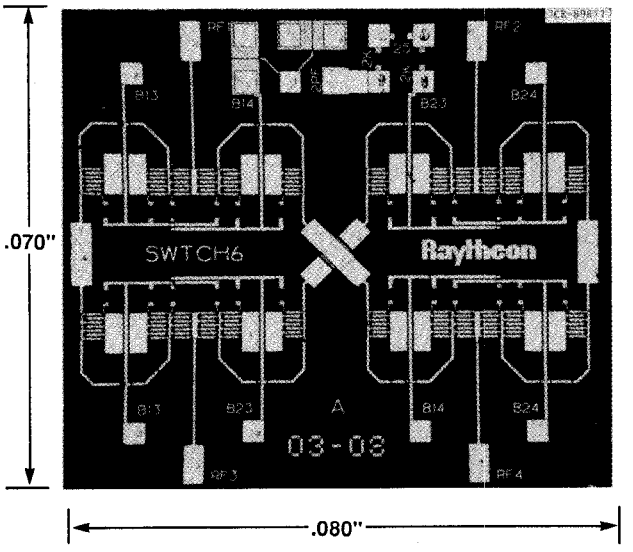

Figure 9. Photograph of 2 x 2 MMIC Switch (70 x 80 mils).

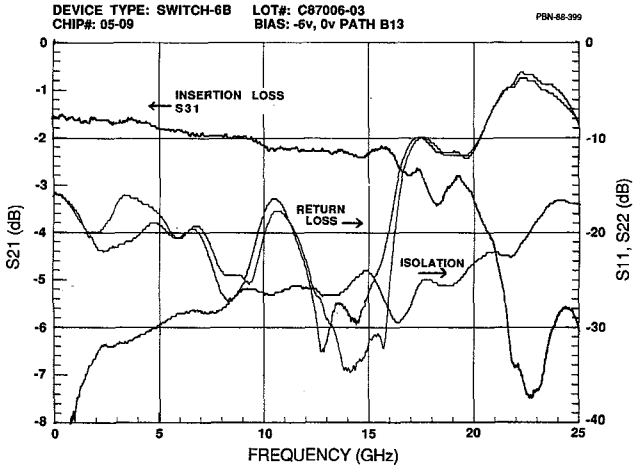

Figure 10. 2 x 2 Switch Performance (Isolation through Crossover).

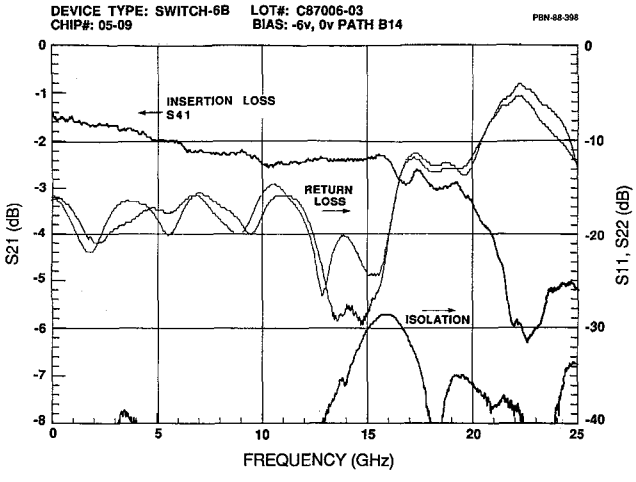

Figure 11. 2 x 2 Swith Performance (Isolation not through Crossover).

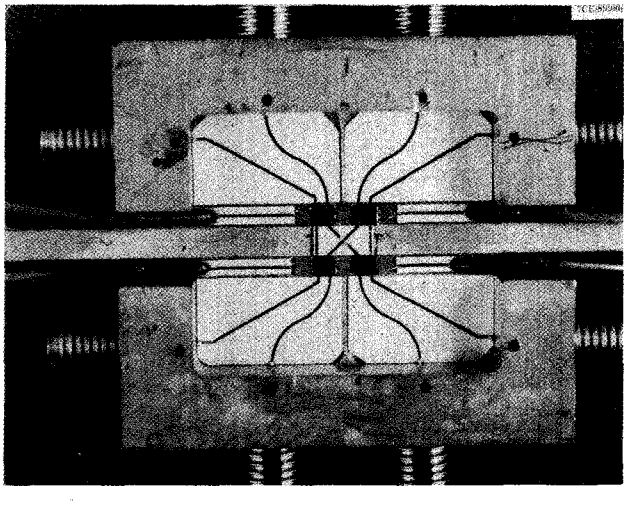

Figure 12. 4 x 4 Switch Assembly.

less than 7 dB to 18 GHz, and the losses in all paths are within 1 dB of one another. Representative isolations are shown in Figure 14. The worst case isolation is 25 dB to 18 GHz, limited by the cross-over isolation of the 2 x 2 MMIC switches. Had the improved 2 x 2 MMICs been used (with reduced cross-over area) all isolations would be better than 30 dB. Best case isolations are off the plot (greater than 40 dB). Representative return losses are shown is Figure 15. All return losses are better than 10 dB to 18 GHz.

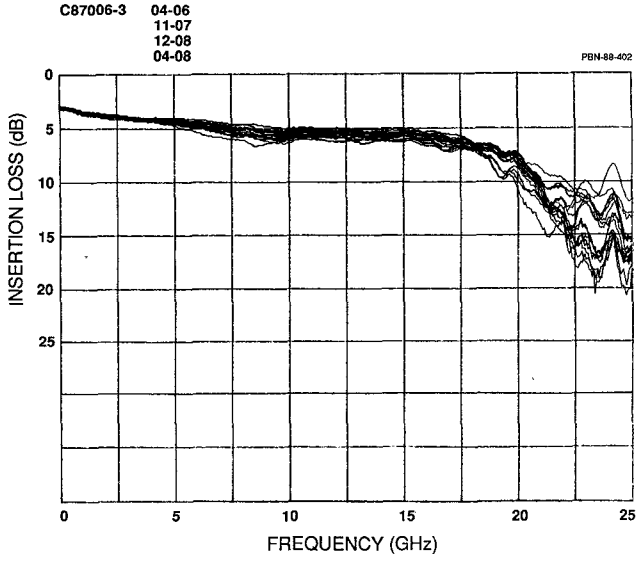

Figure 13. Insertion Losses of 4 x 4 Switch.

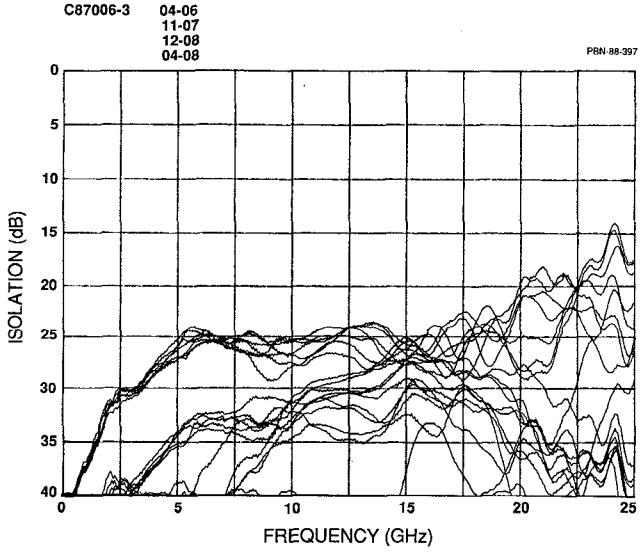

Figure 14. Isolation's for 4 x 4 Switch.

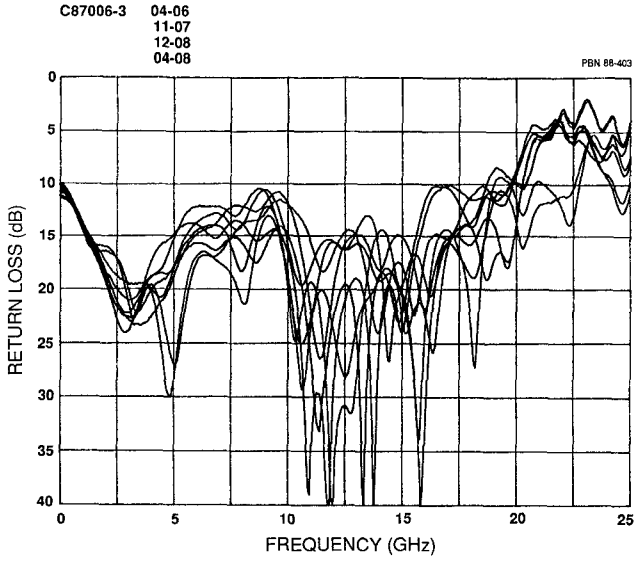

Figure 15. Return Losses for 4 x 4 Switch.

Summary

A series of MMIC component switches has been demonstrated, including 1 x 2, 1 x 4 and 2 x 2 single chip switches. These switches can be used to realize higher order switches, as is illustrated by the 4 x 4 switch. Other high order switches are also possible. For example, two stages of 1 x 4 switches can be used to realize a 1 x 16 switch, or a 4 x 4 switch. The isolation of all MMICs has been demonstrated to be greater than 30 dB to 20 GHz in all states. Insertion loss increases with switch complexity, and is equivalent to 1.5 to 2 dB per 1 x 2 switch.

Acknowledgements

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References

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