

# RF Switching Matrix Enables 128 Channel Architecture and Dynamic Element-to-Receiver Routing

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## Introduction

A high linearity, low-noise radio frequency switching matrix (RFSM) has been created for 1.5T and 3T Magnetic Resonance (MR) imaging subsystems to support a 128-channel count MR system. This is required within the system to route radio frequency (RF) signals from surface coil ports to a remote digital receiver subsystem. Using off-the-shelf components and focusing on integrated circuit layout design, this highly reliable, reproducible RFSM provides an excellent cost and performance benefit.

## Methods

The RFSM is constructed on 370hr substrate using standard commercial components. The RFSM supports dynamic element-to-receiver routing, which allows the user to switch between coils during scanning to increase throughput while using the same quantity of receive channels. This is especially useful while imaging bilateral anatomy, and is accomplished through switch selection and the ability to change signal routing and amplification level during the scan protocol. A subsystem picture is shown below.

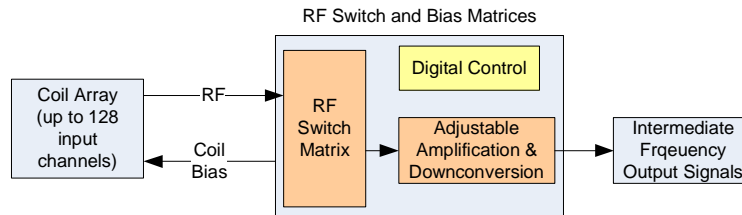


Figure 1: RFSM Block Diagram

The maximum dimension for the RFSM was predetermined by location within the MR system. This requirement challenged the design implementation of on-board stack up, trace placement, and component selection since these factors directly influence channel-to-channel isolation [1]. Crosstalk is undesired in the MR receive chain because it can cause signal leakage (bleeding) from one channel into another; this impacts the geometric sensitivity of the coil, which can ultimately cause image artifacts.

Agilent's Advanced Design System (ADS) software was used to determine optimum printed circuit board trace placement on inside and outside fabrication layers to meet the desired crosstalk specification. Our study found that under a particular stack up, a parallel trace pair 2-5 inches long was 1-2 dB more susceptible to crosstalk than a pair that was less than 2 inches long, even though the gap between 2-5-inch traces was 0.1 mm wider. For the trace pair 5-15 inches long, the gap between traces needed to be increased by 0.25 mm compared to the shorter-than-2-inches pair to maintain the same isolation. Overall crosstalk was found to be no more than -50 dB in this simulation, and crosstalk was 6 dB worse at 3T frequency than at the 1.5T operating point. Optimally, the crosstalk in the receive chain portion of the MR architecture should be much less than the crosstalk within the coils under use (typically about -20 dB). Since the crosstalk caused by trace layout is kept to less than -50 dB, component selection and distribution of the switching sub-blocks become the dominant contributors to the crosstalk of the RFSM.

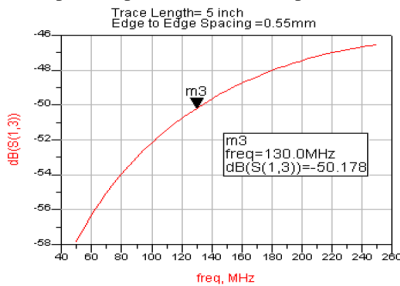


Figure 2: Crosstalk Simulation using Agilent Momentum Software

Up to 128 channels of high current bias circuits are also integrated into the RFSM. This integration reduced overall receive subsystem complexity; however, placing the large quantity of switches, bias circuits, and other components on the limited board space was challenging. A compensation circuit was added to the RF input lines to compensate for impedance degradation due to the bias circuits. This was achieved using the combination of transmission line and lumped components under the guidance of the ADS Momentum simulation.

Onboard programmable intelligent control greatly simplified the trace routing as well; this introduced the capacity of storing multiple instructions to independently control channel switching and gain setting during scan time. This programmable control also has the capability to interface with subsystem control components to simultaneously monitor and communicate system-wide status for safe and reliable system operation.

## Results

The RFSM is capable of dynamic element-to-receiver routing during the patient scan time. Channel-to-channel isolation greater than 35 dB was achieved through extensive fabrication design and careful connector and switching component selection. RFSM performance indicates that the use of ADS and component selection to reduce on-board crosstalk and optimize the RF performance was successful. This matrix boasts a noise figure less than 10dB and an output third order intercept product greater than 22 dBm. Figure 3 is a snapshot of the RFSM fabrication.

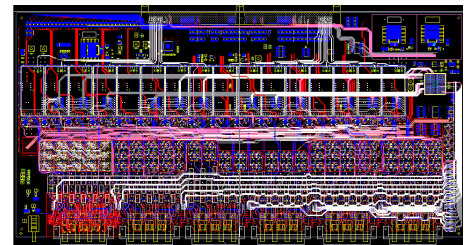


Figure 3: RFSM Fabrication Snapshot

## Conclusion

Dynamic element-to-receiver routing capability is achieved through the selection of RF switching components and the ability to digitally control routing during the scan. This can lead to a throughput and image quality improvement for the diagnostic environment. Crosstalk directly impacts the signal-to-noise ratio and overall image quality. Care was taken during the fabrication and component selection process to minimize crosstalk on this critical component of the 128-channel MR RF receive chain.

## References

[1] A. Pal., et al. "Crosstalk Minimization in Two-Layer Channel Routing". *IEEE TENCON '02*.