# A Comparison of Isolating Amplifier Architectures

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**Introduction:** Parallel MRI is well-established as a technique for accelerating acquisition by reducing the number of phase encode steps needed to obtain an image.[1] The excitation, in contrast, has typically used a single channel to excite a simple slice or slab. The desire to use spatially selective RF pulses to correct through-plane dephasing, $B_1^+$ non-uniformity, or similar tasks has driven an interest in accelerating the RF excitation as well.[2] The Transmit SENSE algorithm has been developed to accomplish this, which is analogous to SENSE, using a transmit array with independently modulated waveforms for each channel.[3]

The SENSE algorithm requires the $B_1$ pattern of the array to be known and stable, but the pattern of a coupled array is sensitive changes in loading. Decoupling the elements of an array stabilizes the patterns in the face of changing loads, thereby improving the results obtained with the SENSE algorithm as well as reducing the amount of power reflected to the amplifiers. Receive arrays commonly use low input impedance preamplifiers to improve isolation between elements[4], but there is currently no analogous method of decoupling transmit arrays that is widely used. Current source (or high output impedance) and low output impedance amplifiers have been suggested as a way to achieve similar decoupling of transmit arrays.[5,6] We have constructed current source, ultra-low output impedance, and standard power amplifiers in order to investigate the relative strengths of the different architectures. The peak output power and isolation that the amplifier architectures provide are the most important metrics for understanding the utility of the different types of amplifiers. Imaging experiments using 128MHz (3T) with eight channel head arrays was used to evaluate the relative performance of the amplifiers. Bench measurements have also been used to obtain the isolation the amplifiers provide.

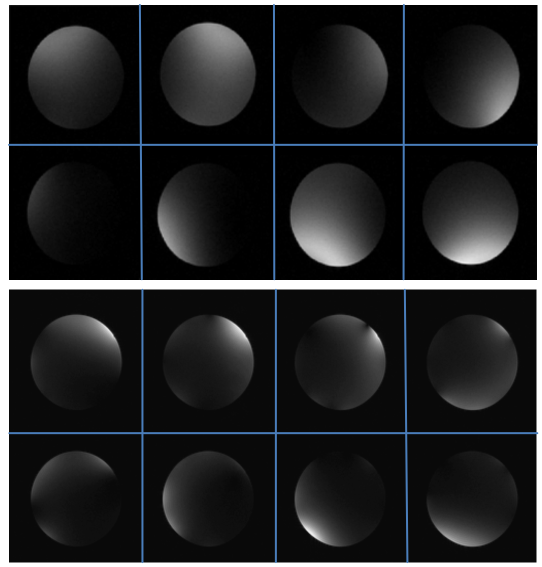

Figure 1: Transmit patterns for two eight channel systems. The top shows current source amplifiers used with a loop array, the bottom shows ultra-low output impedance amplifiers used with a partially decoupled rung array. The current source amplifiers provide higher levels of decoupling, but are unable to generate as much current as the ultra-low output impedance amplifiers.

**Methods:** Eight ultra-low output impedance, and eight current source amplifiers were built using the ARF475FL MOSFET (MicroSemi, Pace Bend, OR). They were paired with array coils sized to fit the human head. The current source amplifiers were used with an array of non-overlapped, series resonant loop elements. The low-output impedance amplifiers were used with an rung array where the nearest neighbors were capacitively decoupled, The matching network for this array is similar to the design used in receive arrays with low input impedance preamplifiers. The current source amplifiers were operated at peak power due since they have reduced output capabilities, but the ultra-low output impedance amplifiers were manually limited to approximately 350W for testing to prevent damage to the coil being used. Sensitivity maps were generated on a 3T system using gradient echo images, as shown in Figure 1.

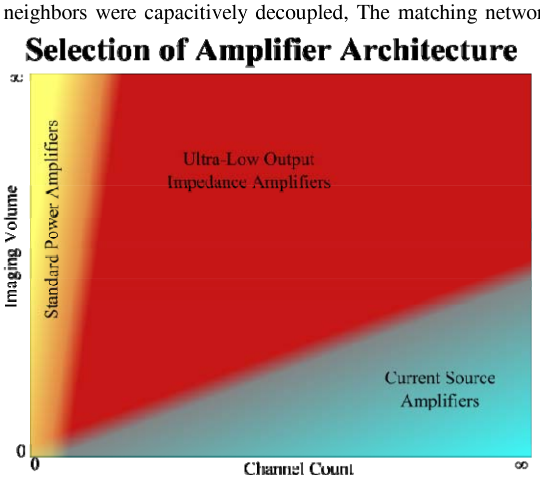


Figure 2: The different amplifier architectures can be selected between based on the required power and isolation. In general, when the imaging region is large and the channel count is low, then a standard power amplifier is suitable. When small imaging regions with large transmit channel counts (i.e. arrays of high density) current source amplifiers excel due to their ability to decouple the array. When arrays and imaging regions are of moderate size, then the ultra-low output impedance amplifiers produce higher power with some isolation.

Isolation was measured by using two decoupled pick-up loops positioned over a coil element. The amplifier under test was connected to the element and powered, but it's input was terminated . The isolation the amplifier provides is taken as the difference between this measurement, and the measurement repeated with the coil terminated in 50Ω.

**Results and Discussion:** Our testing has shown that ultra-low output impedance amplifiers can provide 1kW or more of power delivers to the load, and approximately 11dB of isolation in practical situations. Current source amplifiers, on the other hand, are limited to a few hundred watts delivered to the coil, but isolate array elements to -30dB or better. The results are summarized in Table 1. This indicates that current source amplifiers may be the best options in cases where there are large numbers of highly coupled array elements (e.g. a 64 element loop array for brain imaging), whereas ultra-low output impedance amplifiers are more suitable for smaller channel count arrays that cover larger volumes (e.g. an eight element array for the torso). Standard power amplifiers continue to be a viable option in situations such as body coil transmit coils, where only one or two channels are needed and extremely high powers are desirable. We are in the process of establishing quantitative comparisons of the isolation, output power, and the effect of transmission line losses for the different architectures.

| Architecture | Peak Output Power | Isolation | Impedance |
|---|---|---|---|
| Standard Power | ~1kW | Unknown | Unknown |
| Current Source | ~200W | >30dB | ~2kΩ |
| Ultra-low Output Impedance | ~1kW | ~11dB | ~10Ω |

Table 1: The performance of different amplifiers architectures built using the same MOSFET can be summarized by their output power, isolation, and impedance. Higher output power allows the amplifier to be used with larger coils, higher isolation is useful with higher channel count arrays. Impedance (as seen by the coil) is included for reference. The standard amplifier isolation and impedance will vary based on the exact matching network and transmission line length.

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