Decoupling method for high frequency strip-line probes gives truly independent elements

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Introduction

Parallel imaging techniques such as SENSE [1] have been developed as a means of reducing imaging time by using RF array coil elements to collect data simultaneously, allowing a reduction in the number of phase-encode steps. Transmit SENSE has been introduced which uses separate transmit modes to perform a similar function [2]. Methods which manipulate the phase and amplitude of current in the elements of a coil have been proposed as solutions to the problem of field inhomogeneity and central brightening in volume coils that were predicted, and then experimentally observed, at high fields (>7T)[3]. More recently, a sequential parallel imaging method using strip line elements has been proposed [4] as a possible solution to the transmit inhomogeneity problem. In general sequential parallel imaging relies on the ability to isolate individual elements around a volume coil so that elements can transmit independently or in sequence, whilst being able to receive on all elements simultaneously. To get good field homogeneity, and thus increase SNR, more elements around the cylinder are used. However, coupling between the resonant elements increases with proximity of neighbouring elements and with frequency [5]. This makes the individual elements difficult to tune and therefore the SNR of the coil is reduced significantly. SENSE or other receive-only coil arrays can avoid this problem as they need only to be noise matched and can therefore be isolated using a large effective impedance of the pre-amplifier. This approach is not possible for transmit/receive coils as the elements need to be matched for transmission. Often, linear strip lines are favoured rather than loops for high frequency probes [6] and while it is possible to tune individual elements on a four element strip line head-coil to all resonate at 128 MHz (3T) [4], the coupling effects at higher frequencies or for more elements make this problem worse. We are proposing that a solution to this problem using inter-element capacitive decoupling strips is feasible at 300 MHz. Once optimally positioned between quarter-wave elements, the decoupling strip allows each element to be driven with minimal coupling to its neighbours. This method can then be employed to construct a fully independent *n*-element transceive array probe.

Method

Initial bench tests using two identical 200 mm strip-line elements 100 mm apart were conducted similar to those shown in Fig.1. The strips were 10 mm above the ground-plane, shorted at one end and capacitively tuned at the other. They form an approximate quarter-wave line at 300 MHz. Small loop search coils attached to a network analyser were used to determine the coupling ratios and resonant frequencies. Similar shorter strips were connected between the lines and capacitively coupled to both lines.

A finite element modelling package (CST Microwave Studio) was used to evaluate the proposed method by firstly re-creating the dual line experiment. One element may be driven and the level of coupling, resultant current in each element and the overall magnetic field produced may be observed. The optimum position for the decoupling strip was determined iteratively be analysing the ratio of current flowing in each element at the resonant frequency. Further tests have been carried out to demonstrate that a series of 3 strips side-by-side could be decoupled using this technique. Finally an eight strip cylindrical head-coil model was created and driven with and without decoupling strips together with suitable loading.

Results

For the experimental dual-element circuit, with no attempt at decoupling, the resonant frequency displays characteristic splitting. By introducing a capacitively coupled decoupling strip-line at an optimum position the coupling can be eliminated giving two truly independent elements tuned to the same frequency. Example modelling results for 3 linear elements are displayed in Figs. 2 and 3. Figure 2 shows the coupling between three strip line elements side-by-side where the central element is being driven and no attempt at decoupling has been made. The coupling between the central element and the outer elements causes splitting of the resonant frequency as expected. Figure 3 shows the same three elements but this time with decoupling strips at optimum positions. The splitting due to coupling is greatly reduced and much less energy is transferred to the outer strips so the magnetic field from the driven strip is much stronger. No attempt has been made to restore a specific resonant frequency in this demonstration as the additional decoupling does lower the resonant frequency. However, all three strips do now have the same resonant frequency and are effectively independent. Eight element cylindrical head probe models show similar behaviour with large reductions in coupling factor. The optimum position for the strips has yet to be determined but preliminary tests show an 8dB reduction in coupling between driven and neighbouring strips.

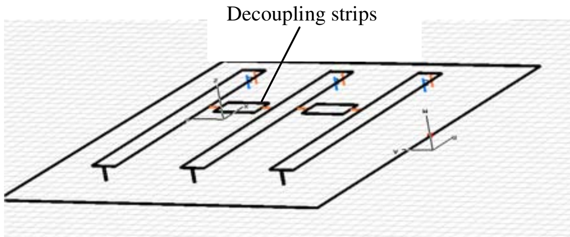

Figure 1

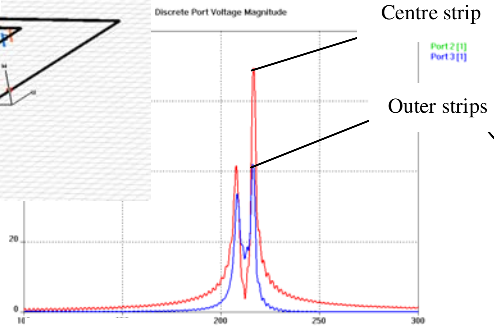

Figure 2

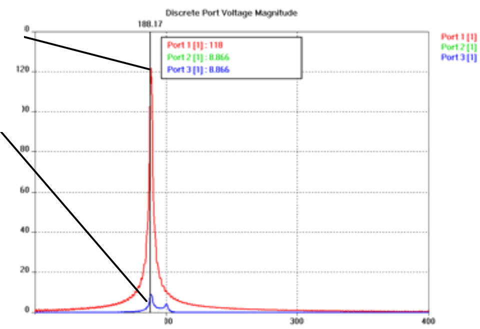

Figure 3

Discussion and Conclusion

We have demonstrated that this technique works on the bench to decouple two strips very effectively. Both strips were driven independently to verify that the difference in frequency after the decoupling strip was added was not due to changing of one resonance. Finite element modelling has been used to demonstrate that a series of strips can be fully decoupled. We have demonstrated that the principle works for a full eight strip cylindrical head probe model. Preliminary investigations into decoupling modelled strips loaded with head phantoms are returning encouraging results. The current distribution on a quarter wave element makes this method eminently suitable for the building of a hemi-spherical head coil.

References

[1] KP Pruessmann et al. *magnetic resonance in medicine*, 49:144-150, 2003; [2] U Katscher, et al. *magnetic resonance in medicine 49:144-150, 2003;* [3] CM Collins, et al. *Journal of Magnetic Resonance imaging* 21:192-196, 2005; [4] A Magill, et al, in: Proceedings of the 13th Annual Meeting of ISMRM, Miami, p183, 2005; [5] MD Harpen, et al *Phys. Med. Biol* Vol 33 No. 11 1285-1289, 1988; [6] G Adriany et al. *Magn Reson Med; 53: 434-445, 2005;*