Noise Cancellation in Two Channel Coil Array Using a Lamped Element Rat Race Coupler

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Introduction

Noise decoupling in MRI coil arrays is important for achieving the optimal SNR at the combined output. The noise correlation between coil elements has been studied in [1-3], where the focus was on finding the conditions for correlated noise decoupling. Thus, 100% noise decoupling in two coil array was achieved in [2] by providing the required phase shift between two array outputs or in [3] by the specific orientation of the coil and sample geometry. In this paper a lumped element Rat Race coupler [4] is used to combine the two coil array outputs so that the correlated noise is canceled out at one of the Rat Race outputs. The theoretical analysis and experimental data are presented and discussed below.

Theory

The Rat Race coupler has been in common use in RF applications for decades. A physically small design at MRI frequencies can be realized by using the lumped elements [4] as shown in Figure 1. An attractive property of a Rat Race is to combine the two input signals **a** and **b** so that they are added in phase at the "sum" output and out of phase at the "difference" output with a factor 1/sqrt(2). If **a** and **b** are similar, the signal at the "difference" port vanishes. This property of a Rat Race can be used to cancel out the correlated noise in a two channel coil array. In order to verify this, a the two channel noise equivalent circuit [1-3] has been considered in combination with a Rat Race circuit, as shown in Figure 2, and a noise analysis using Spice software has been performed. In Fig. 2 the resistor R_{12} represents the correlated noise source and R_1=R_2–the uncorrelated ones.

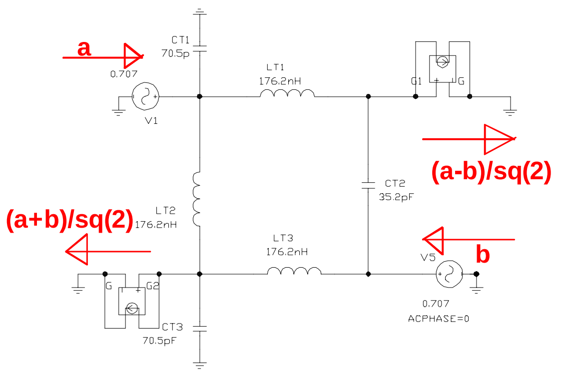

Figure 1. A Lumped element Rat Race coupler

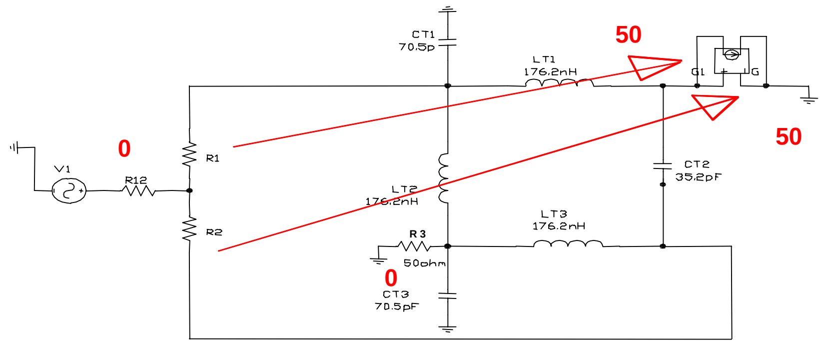

Figure 2. A two channel noise model connected to a Lumped element Rat Race

The result of analysis at the "difference" port is plotted in Figure 3. Curve 1-is a normalized total noise produced by the two uncorrelated sources R_1 and R_2. Curve 2-is the noise contribution of the correlated source R_{12} at the "difference" port and curve 3 is the noise contribution of the 50 Ohms termination at the "sum" port. Noise described by curves 2 and 3 vanishes at the resonance frequency (64 MHz).

Experiment and Discussion

In order to confirm the analysis results the prototype circuit matched to 50 ohms characteristic impedance has been built. The 50 ohms load and Noise sources 360A, 360B by Agilent has been used instead of R_{12} and 0-21dB attenuators instead of R_1 = R_2. The R_{12} noise sources have been measured first using a Spectrum analyzer. The noise power of the 50 ohms resistor was found to be equal to -111.5 dBm (for the resolution bandwidth and the preamplifier gain used in the setup), while the noise of the 360A and 360B sources was found to be -106.3dBm and -97.3 dBm respectively. The summary of circuit noise measurements is given in Table 1. It is clearly seen that the noise added by the circuit negligible (see columns 1,5). The noise at the "difference" port does not exceed the noise of a 50 ohm resistor for any correlated noise sources, whereas the excess noise is seen at the "sum" port of the Rat Race (see rows 2,3). This demonstrates the absence of correlated noise at the 'difference" port.

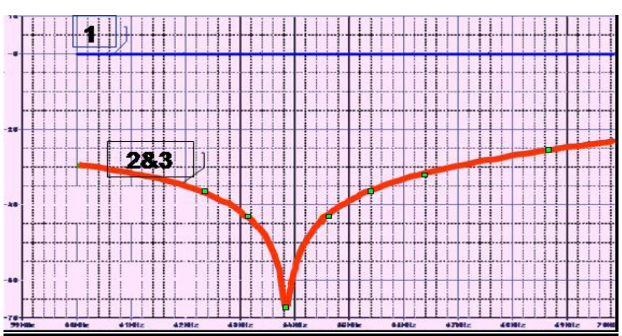

Figure 3 Noise analysis data at Rat Race "difference " port

#	Measured Data in dB	at ∑ - port				at Δ - port
	Correlated Noise Source	Att 0dB	Att 6dB	Att 9dB	Att 21dB	Att 0- 21dB
1	50 ohms Termination	-111.4	-111.6	-111.3	-111.7	-111.2
2	SNS ENR = 5.26dB Hot	-106.3	-108.9	-110.6	-111.3	-111.9
3	SNS ENR = 15.65 dB Hot	- 97.3	-102.3	-106.0	-110.6	-111.6

Table 1. Noise measurement results at two Rat Race outputs.

References

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