CHAPTER 5

DESIGN OF OCTAGON SHAPED 12 CHANNEL PHASED ARRAY RF COIL FOR HUMAN SPINE MRI

5.1 INTRODUCTION

In Magnetic resonance imaging most of the recently existing RF receive coils are on the form of phased array RF coils. A separate volume coil is used as transmit coil for producing homogeneous field which is surrounding the object to be imaged. The astonishing effort of the phased array RF coil approach is to achieve high SNR and extended Field of view by using a set of RF coils. In phased array RF Coils mutual inductance and parasitic capacitances will lead to undesired transfer of signal to the neighbouring coils. This increases the coupling of noise signal to the neighbouring coils and consequently reduces the SNR of the received signal (Vojtisek et al 2011).

The overlapping of the neighbouring coil will make the mutual inductance almost close to zero. In the overlapped coil arrangements capacitor is placed at the center of the coil. The EMF induced in one coil due to the other coil and vice versa is cancelled due to the presence of capacitor. The overlapping distance and capacitor value is very important for this to happen. Where as in nonoverlapped structure the capacitor is not used. Therefore the spacing between the coils will be the main factor to reduce the effect of mutual impedance. The major objective to prefer phased array coils are to obtain the
images from the local region of the body part to be imaged. But the overlapped coils may receive the signal from overlapped region. This weakens the concept of local imaging and reduces the SNR. The simplest approach in phased array coil implementation is to keep some spatial distance between neighbouring coils to reduce the mutual coupling between coil elements.

Mutual coupling is inversely proportional to the spacing between neighbouring channels. The increase in spatial distance between channels will reduce the mutual coupling. At the same time more spatial distance between the neighbouring channels will restrict the number of channels within the given FOV. One more way to reduce the mutual coupling is to place the lumped capacitors between transmission lines. Such capacitors are called as decoupling capacitors. The voltage across the capacitor will counterbalance the induced electromotive force of mutual coupling effect (Lee et al 2002).

In this chapter an octagon shaped 12 channel phased array RF coil structure is proposed for 1.5 Tesla MR imaging. The structure is impedance matched by using L Type matching network. In order to apply optimized type 1 matching, a small adjustment is made in the original geometry of the octagon. The quality factor of the octagon geometry is evaluated. Single channel octagon is extended to construct a non-overlapped 12 channel phased array RF coil. The performance of the RF coil is improved by designing the appropriate matching network. Return loss analysis of the octagonal geometry is performed for various values of spatial distances between neighbouring channels.
5.2 SINGLE CHANNEL OCTAGON SHAPED RF COIL STRUCTURE

A single channel octagon shaped surface type RF coil structure is shown in Figure 5.1. The side length of octagon is 36 mm and width of octagon is selected as 10 mm. This microstrip based octagon structure can behave as inductive reactance. In order to resonate the structure at 63.87 MHz a tuning capacitor of appropriate value is to be added in series with the octagon structure. The octagon structure is divided as two equal sections and the inductive reactance for half of the section (Figure 5.2 a) was evaluated from smith chart Figure 5.2(b). The total inductance of the coil is two times the inductance of the half section. The tuning capacitor value is determined from the series resonance frequency formula.

Figure 5.1 Octagon shaped surface type RF coil
Figure 5.2  Half section Octagon Coil a) Schematic Structure b) input impedance evaluation from smith chart

Smith chart input impedance values at resonance frequency of 63.87 MHz is $Z_{in} = 50 \times (4.6736 \times 10^{-5} + j0.1476) \, \Omega$. The positive sign in the imaginary part says the reactance is inductive in nature. A model calculation for tuning capacitor evaluation is shown below.

$$Z_{in} = R + jX_L = 50 \times (4.6736 \times 10^{-5} + j0.1476) = 0.0023368 + j7.38 \, \Omega$$

$$X_L = 7.38$$

$$L_1 = L_2 = \frac{7.38}{2\pi \times 63.87 \times 10^6} = 18.39 \, \text{nH}$$

$$L_{eq} = 2 \times L_1 = 36.78 \, \text{nH}$$

$$f = \frac{1}{2\pi \sqrt{L_{eq} C}}$$

$$C = \frac{1}{(2\pi f)^2 L_{eq}} = 168.83 \, \text{pF}$$
The calculated tuning capacitance value is $C_t = 168.83$ pF. The microstrip part of the proposed structure is implemented in the layout option of ADS 2011.

![Unmatched octagon structure](image.png)

**Figure 5.3** Unmatched octagon structure  
a) Schematic structure  
b) Input impedance evaluation from smith chart

Figure 5.3a) shows the schematic structure of unmatched 10 mm width octagon shaped structure. In the structure a spacing of 2 mm is provided to connect the tuning and decoupling capacitor in the upper and lower sides of the octagon respectively. The capacitor $C_d = 0.1$ pF is used as decoupling capacitor and $C_t = 168.83$ pF is used as tuning capacitor. The input impedance of the unmatched RF coil is determined from smith chart plot of ADS scattering parameter simulation as shown in Figure 5.3 b).

### 5.2.1 Matching Network Design

Matching network element values will be determined from the input impedance of unmatched octagonal structure. As discussed in previous chapters there are four different L Type matching network configurations. The first shunt element (either C or L) and input reactance (Capacitive or
Inductive) of the unmatched RF coil will decide a particular matching network configuration as shown in Figure 5.4 (a) to 5.4 (f).

The first shunt element is capacitor for type 1 matching network and inductor for type 2 matching network. If the input reactance of the unmatched RF coil is inductive ($X_L$), then in order to cancel the inductive reactance a capacitive reactance ($C_{ad}$) is added in series with the matching network as shown in Figure 5.4 (a) & (b). If the input reactance of the unmatched RF coil is capacitive ($X_c$) then in order to cancel the capacitive reactance an inductor ($L_{ad}$) is added in series with the matching network as shown in Figure 5.4 (c) & (d). The further simplification of Type1 matching network with shunt capacitor shown in Figure 5.4 (e). It is simplified to obtain the optimized matching network (modified Type1) with only capacitors ($C_1$ & $C_2$).

![Figure 5.4 L Type matching network configuration](image-url)
Therefore instead of focussing all possible matching network configurations, let us look into the design of Type1 matching network. The input impedance of the unmatched octagon shaped RF coil is evaluated from ADS scattering parameter simulation. The smith chart plot of the scattering parameter simulation is shown in Figure 5.3.b). The input impedance $Z_{in} = 50*(0.00007 + j0.00271)$ should be matched to the $50\Omega$ source impedance using the Type1 matching network configuration shown in Figure 5.4 e).

Equations (3.2) to (3.4) described in chapter 3.3 are used to calculate $L$ and $C$ values of the Type 1 matching section. The values of the shunt and series matching elements are $C = 5.9565\, nF$, $L = 1.0424\, nH$.

The real input impedance $(R_{in})$ of the octagon shaped RF coil $(Z_{0}*0.0007)$ is matched to $50\, \Omega$ by using Type 1 matching network elements $C$ & $L$. The imaginary inductive reactance $(0.1355)$ present at the input side of octagon shaped RF coil is eliminated by adding an opposite type of reactance in series with the matching network. Thus the inductive reactance is removed by adding an exact amount of capacitive reactance. The value of additional capacitance $(C_{ad})$ is determined as follows.

From Figure 5.3b),

$$X_L = Z_0* (0.00271) = 0.1355\, \Omega$$

$$X_c = \omega = 0.1355$$

$$C_{ad} = \frac{1}{0.1355 * \omega} = 18.39\, nF$$

This additional capacitor $C_{ad} = 18.39\, nF$ is connected in series with the matching network.
5.2.2 Results and Discussion

The microstrip part of the proposed octagon shaped structure is implemented in a layout option of ADS 2011. A 35 μm copper transmission line of 10 mm width and as specified in Figure 5.1 is implemented in a FR4 dielectric material with 1.6 mm thickness. The lumped elements such as tuning capacitor (Ct), decoupling capacitor (Cd) and matching elements (C, L & Cad) are inserted at proper positions of the RF coil. The layout design is exported as Electromagnetic model to perform Co-simulation between lumped and distributed sections in ADS schematic.

S Parameter Co-simulation is performed to obtain the return loss behaviour of the proposed octagon shaped 1.5 Tesla RF coil structure with type1 matching circuit as shown in Figure 5.5 a) & 5.5 b). The return loss result of 26.93dB shows that a perfect impedance matching is achieved for the proposed coil structure at 63.87 MHz.

Figure 5.5 Octagon shaped RF coil with matching network
(a) Schematic view (b) Return loss plot
The matching network consists of lumped Capacitors and inductor. The presence of inductor in the matching network will degrade the performance of RF coil due to ohmic and parasitic effect. The optimized matching network in Figure 5.4 e) will give a solution for this issue. The design is already discussed in chapter 4.2.3. In Type 1 matching network Capacitor Cad is selected to cancel the input reactance \( (X_{in}) \) of the coil. The inductive reactance of matching network \( (2\pi f_0 L) \) is obtained from \( X_L \), and Cad is selected to cancel the remaining amount of inductive reactance \( (X_{in} - 2\pi f_0 L) \) available in \( Z_{in} \). The subtraction of series inductor reactance \( (X_L) \) from input reactance of the coil produces a negative effect as shown in the below calculation. Therefore for the proposed octagon shaped RF coil structure modified Type 1 matching procedure is not applicable.

\[
Z_{in} = 50 \times (0.00007 + j0.00271) = 0.0035 + j0.1355 \Omega
\]

Matching Elements \( C = 5.9565 \text{nF}, L = 1.0424 \text{nH}, \text{Cad} = 18.39 \text{nF} \)

\[
X_L = 2\pi f_0 \times 1.0424 \times 10^{-9} = 0.4183.
\]

\[
X_{in} - X_L = -0.2828.
\]

In order to verify the behaviour of proposed octagon shaped RF coil structure with Type 1 matching network, the width dimension of the RF coil is varied from 4 mm to 14 mm. The return loss results obtained from the scattering parameter simulation are given in Table 5.1. The equivalent inductance \( (\text{Leq}) \), Tuning capacitor \( (\text{Ct}) \) and input impedance \( (Z_{in}) \) parameters of the unmatched octagon shaped RF coil are also listed in Table 5.1. The result shows that for lower values of RF coil width the return loss is good. The increase in coil width increases the mutual coupling between transmission lines. This reduces the effectiveness of impedance matching circuit and consequently lesser value of return loss is obtained.
Table 5.1 Return loss performance for various RF coil width dimensions

<table>
<thead>
<tr>
<th>Width (mm)</th>
<th>Un matched RF Coil Parameters</th>
<th>Matching Elements</th>
<th>Return loss -S11 (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Leq (nH)</td>
<td>Ct (pF)</td>
<td>Zin (10^{-4}\Omega)</td>
</tr>
<tr>
<td>4</td>
<td>74.407</td>
<td>83.451</td>
<td>1.8+j32.5</td>
</tr>
<tr>
<td>5</td>
<td>64.190</td>
<td>96.734</td>
<td>1.6+j29</td>
</tr>
<tr>
<td>6</td>
<td>56.067</td>
<td>110.75</td>
<td>1.3+j30</td>
</tr>
<tr>
<td>7</td>
<td>49.663</td>
<td>125.03</td>
<td>1.1+j33.7</td>
</tr>
<tr>
<td>8</td>
<td>44.604</td>
<td>139.21</td>
<td>0.9+j31.8</td>
</tr>
<tr>
<td>9</td>
<td>40.443</td>
<td>153.53</td>
<td>0.8+j29.4</td>
</tr>
<tr>
<td>10</td>
<td>36.78</td>
<td>168.83</td>
<td>0.7+j27.1</td>
</tr>
<tr>
<td>11</td>
<td>33.59</td>
<td>184.86</td>
<td>0.6+j26.2</td>
</tr>
<tr>
<td>12</td>
<td>30.849</td>
<td>201.28</td>
<td>0.4+j24.9</td>
</tr>
<tr>
<td>13</td>
<td>28.432</td>
<td>218.39</td>
<td>0.3+j23.8</td>
</tr>
<tr>
<td>14</td>
<td>26.314</td>
<td>235.97</td>
<td>0.3+j24.9</td>
</tr>
</tbody>
</table>

5.3 MODIFIED OCTAGON SHAPED RF COIL STRUCTURE

The octagon shaped RF coil structure discussed in the previous section was having the limitation in matching network components. The matching network consists of three lumped components including an inductor. A matching network fully made up of capacitors is not applicable for the octagon structure discussed in the previous section. This inability is due to the lesser value of inductive reactance present in the unmatched octagon structure. In order to eliminate this shortcoming a modification is proposed in the octagon structure.
Figure 5.6  Octagon shaped surface type RF coil with center transmission line

Figure 5.6 shows the octagon shaped RF surface coil with center transmission line. The structure dimension is same as that of the structure shown in Figure 5.1 except the center transmission line. This center transmission line will give additional inductive reactance compared to the octagon structure without center transmission line. This structure is compatible in using modified Type1 matching with matching elements as only capacitors.

Figure 5.7  Half section modified octagon a) Schematic structure b) Input impedance evaluation from smith chart
The input impedance evaluation is performed using half section octagon coil with center transmission line as shown in Figure 5.7. It shows that for half section inductive reactance of (0.0030+j7.45) Ω for 10 mm width RF Coil. The input impedance of half section octagon coil without the center transmission line is (0.0023+j7.38) Ω. Therefore the addition of center transmission line will increase the input impedance of the coil.

### 5.3.1 Matching Network Design

The main objective to insert the center transmission line in the existing octagon structure is to apply modified type1 matching for the structure. Figure 5.7 b) shows the input impedance of the half section modified octagon coil. The reactance of the input impedance is inductive in nature. Inductive reactance evaluation and the determination of tuning capacitance ($C_t$) are as follows.

\[
Z_{in} = R + jX_L = 50 \times (6.0229 \times 10^{-5} + j0.1490) = 0.003 + j7.45 \Omega
\]

\[
X_L = 7.45
\]

\[
2\pi L = 7.45
\]

\[
L_1 = L_2 = \frac{7.45}{2\pi \times 63.87 \times 10^6} = 18.564 \text{nH}
\]

\[
L_{eq} = 2 \times L_1 = 37.129 \text{nH}
\]

\[
f = \frac{1}{2\pi \sqrt{L_{eq} C}}
\]

\[
C_t = C = \frac{1}{(2\pi f)^2 L_{eq}} = 167.24 \text{pF}
\]
The unmatched octagon shaped RF coil with center transmission line is shown in Figure 5.8. The input impedance of the unmatched octagon shaped RF coil is evaluated from ADS scattering parameter simulation. The smith chart plot of the scattering parameter simulation is shown in Figure 5.8.b). The input impedance $Z_{\text{in}} = R_{\text{in}} + jX_{\text{in}} = 50 \times (0.0034 + j0.6499)$ should be matched to the $50\Omega$ source impedance using the Type1 matching network configuration shown in Figure 5.4 e).

Equations (3.2) to (3.4) described in chapter 3.3 are used to calculate $L$ and $C$ values of the Type 1 matching section. The values of the shunt and series matching elements are $C = 0.85325 \, \text{nF}$, $L = 7.2526 \, \text{nH}$.

The real input impedance ($R_{\text{in}}$) of the octagon shaped RF coil ($Z_0*0.0034$) is matched to $50 \, \Omega$ by using Type 1 matching network elements $C$ & $L$. The imaginary inductive reactance ($32.495$) present at the input side of modified octagon shaped RF coil is eliminated by adding an opposite type of reactance in series with the matching network. Thus the inductive reactance is
removed by adding an exact amount of capacitive reactance. The value of additional capacitance (Cad) is determined as follows.

From Figure 5.3b), $X_{in} = Z_0 \ast (0.6499) = 32.495 \, \Omega$

$$X_C \omega = 32.495$$

$$C_{ad} = \frac{1}{32.495 \ast \omega} = 76.684 \, \text{pF}$$

This additional capacitor Cad = 76.684 pF will be connected in series with the matching network. But there are three number of matching components such as C, L and Cad are present in the matching network. The matching element L is eliminated by extracting the amount reactance due to L ($X_L$) from the input reactance ($X_{in}$) itself. The remaining reactance ($X_{in} - X_L$) will be nullified by adding a series capacitor $C_2$.

The capacitor $C_2$ is,

$$C_2 = \frac{1}{\omega_0 (X_{in} - X_L)}$$

$X_{in} = 32.495, \quad X_L = 2.9105$

$$C_2 = \frac{1}{\omega_0 (32.495 - 2.9105)} = 84.229 \, \text{pF}.$$  

The elements of modified Type1 matching network are, shunt capacitor $C=C_1= 0.85325 \, \text{nF}$ and series capacitor $C2= 84.229 \, \text{pF}$. 
Figure 5.9 Single channel modified octagon shaped RF coil

Figure 5.10 S parameter simulation results a) Return loss behaviour, b) impedance plot in smith chart

Figure 5.9 shows the schematic structure of 10 mm width modified octagon structure with modified type1 matching network. ADS scattering parameter simulation is performed to verify the return loss behaviour of the structure.
The return loss behaviour and impedance matching performance are illustrated in Figure 5.10 a) & 5.10 b) respectively. The impedance matching is indicated in terms of smith chart plot. At resonance frequency of 63.87 MHz the marker position occurs exactly at the center of smith chart, indicating the perfect impedance matching at the desired frequency.

5.3.2 Quality Factor Evaluation

The lumped element equivalent circuit of the modified octagon shaped structure is considered for quality factor evaluation. The input impedance of the unmatched 10mm width octagon shaped RF coil is illustrated in Figure 5.8 b). The impedance consists of resistive value of 0.17Ω and inductive reactance of 32.495 Ω. In the equivalent circuit of octagon shaped RF coil a modified Type1 matching elements C1 and C2 followed by a series connection of Rin and Lin is used for representing unmatched RF coil input impedance.

![Lumped equivalent circuit of Octagon shaped RF Coil](image)

Figure 5.11 Lumped equivalent circuit of Octagon shaped RF Coil

Figure 5.11 shows the lumped element equivalent circuit of modified octagon shaped RF coil. The input impedance for the circuit is analytically derived, and the quality factor is evaluated using Equations (4.10) to (4.12).
5.3.3 Results and Discussion

In the previous section a 10 mm width octagon structure with center transmission line was discussed for matching network design and quality factor evaluation. The proposed octagon shaped RF coil structure is verified for various width values ranging from 4 mm to 14 mm. FR4 substrate of thickness 1.6 mm, conductive strip layer of 35 μm is used in all the simulations.

Table 5.2 Resonance Parameters and Input Impedance

<table>
<thead>
<tr>
<th>S. No</th>
<th>Coil Width (mm)</th>
<th>Reactance of half section ($X_{L,Half}$)</th>
<th>Equivalent Inductance $L_{eq}$ (nH)</th>
<th>Tuning Capacitor $C_t$ (pF)</th>
<th>Input impedance $Z_{in}$ (Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>15.085</td>
<td>75.179</td>
<td>82.594</td>
<td>0.175 + j 47.535</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>12.970</td>
<td>64.639</td>
<td>96.062</td>
<td>0.145 + j 40.365</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>11.335</td>
<td>56.49</td>
<td>109.92</td>
<td>0.125 + j 34.970</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>10.030</td>
<td>49.987</td>
<td>124.22</td>
<td>0.110 + j 30.740</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>9.055</td>
<td>45.128</td>
<td>137.60</td>
<td>0.250 + j 42.545</td>
</tr>
<tr>
<td>6</td>
<td>9</td>
<td>8.185</td>
<td>40.792</td>
<td>152.22</td>
<td>0.210 + j 37.245</td>
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<tr>
<td>7</td>
<td>10</td>
<td>7.450</td>
<td>37.129</td>
<td>167.24</td>
<td>0.170 + j 32.495</td>
</tr>
<tr>
<td>8</td>
<td>11</td>
<td>6.805</td>
<td>33.914</td>
<td>183.09</td>
<td>0.140 + j 28.805</td>
</tr>
<tr>
<td>9</td>
<td>12</td>
<td>6.220</td>
<td>30.999</td>
<td>200.31</td>
<td>0.035 + j 15.335</td>
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<tr>
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<td>5.730</td>
<td>28.557</td>
<td>217.44</td>
<td>0.030 + j 13.830</td>
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<tr>
<td>11</td>
<td>14</td>
<td>5.310</td>
<td>26.464</td>
<td>234.64</td>
<td>0.025 + j 12.520</td>
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</table>
Table 5.2 shows the resonance parameters and unmatched input impedance of modified octagon shaped RF coil. The width value of the RF coil is increased in steps of 1mm and for each width values equivalent inductance and tuning capacitor are evaluated as shown in Table 5.2. The microstrip part of the RF coil is implemented in layout option of the ADS 2011. This layout structure is exported as EM-Model to ADS Schematic and lumped tuning (C_t) and decoupling (Cd) capacitors are connected for obtaining the input impedance (Zin) of unmatched RF coil. The unmatched input impedance of the RF coil is used for evaluating modified Type1 matching network elements such as C1 and C2. This matching network was connected at the input side of octagon shaped RF coil. The unmatched input impedance and matching network element values are used for determining unloaded quality factor of the RF coil. Scattering parameter simulation is performed to obtain the return loss values for different width values of the RF coil. The quality factor and return loss values obtained from ADS Co-simulation are indicated in Table 5.3 for various values of RF coil width ranging from 4 mm to 14 mm.

The lower values of RF coil width produces better return loss of greater than 30 dB. In the higher values of width ranging from 12 mm to 14 mm return loss values are reduced. These lesser return loss shows the impedance matching is disturbed due to mutual coupling between nearby transmission lines. The increase in coil width makes the center transmission line closer to the sides of octagon. This increases the mutual coupling between transmission lines. Once the mutual coupling comes into effect the input impedance of the unmatched RF coil will deviate from the value considered for matching network design. This constitutes the reduction in return loss value for higher value of RF coil width.
Table 5.3 Quality factor and return loss values for various RF coil width

<table>
<thead>
<tr>
<th>S. No</th>
<th>Coil Width (mm)</th>
<th>Input impedance $Z_{in}$ (Ω)</th>
<th>Matching Elements</th>
<th>Return loss - $S_{11}$ (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Shunt Capacitor C1 (nF)</td>
<td>Series Capacitor C2 (pF)</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
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<td>0.9955</td>
<td>76.736</td>
</tr>
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<td>7</td>
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<td>1.0614</td>
<td>87.75</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>0.250 + j 42.545</td>
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<tr>
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<td>9</td>
<td>0.210 + j 37.245</td>
<td>0.76739</td>
<td>73.265</td>
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<td>7</td>
<td>10</td>
<td>0.170 + j 32.495</td>
<td>0.85325</td>
<td>84.229</td>
</tr>
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<td>8</td>
<td>11</td>
<td>0.140 + j 28.805</td>
<td>0.94051</td>
<td>95.244</td>
</tr>
<tr>
<td>9</td>
<td>12</td>
<td>0.035 + j 15.335</td>
<td>1.883</td>
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<tr>
<td>10</td>
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<tr>
<td>11</td>
<td>14</td>
<td>0.025 + j 12.520</td>
<td>2.2282</td>
<td>218.54</td>
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</table>

5.4 ANALYSIS OF OCTAGON SHAPED PHASED ARRAY RF COIL

The octagon shaped RF coil with center transmission line discussed in the previous section is focused for multichannel implementation of RF surface coil. The phased array RF coil structure will act as receive only RF coil for capturing Human spine MRI applications. The Field of View (FOV) for the proposed phased array RF coil is fixed as 450 mm x 300 mm. The number channels to be accommodated within the FOV depends on the area of single octagon structure and the spacing between nearby octagonal channels. As per the results from Table 5.3 lower width values are giving
better return loss. The quality factor values of greater than 100 are good for MRI RF Coils (Wu et al 2010). Therefore in order to bring more number of channels within the FOV, an 8 mm width octagon structure is selected for phased array implementation.

5.4.1 Design implementation

Single channel octagon shaped coil is placed in an array of 3 x 4 configuration to obtain a 12 channel phased array RF coil. The spacing C between nearby octagons is decided from Pythagoras' theorem as indicated in Figure 5.12. A 12 channel phased array RF coil with spacing \( C = 11.3137 \text{mm} \) (a=8mm) is shown in Figure 5.13. The spatial distance between neighbouring channels is maintained as \( C = 11.3137 \text{ mm} \) for all the 12 channels. Figure 5.14 shows the return loss result of 12 channel phased array RF coil for a spatial distance of 11.3137 mm. In all the 12 channels same value of tuning capacitor \( (C_t) \), matching capacitor \( (C_1, C_2) \) and decoupling \( (C_d) \) capacitors are used.

\[
C = \sqrt{a^2 + a^2}
\]

Figure 5.12 Spatial distance calculation between neighbouring octagons
Figure 5.13  Schematic view of octagon shaped 12 channel phased array

RF Coil
5.4.2 Results and Discussion

The spacing between neighbouring coils is varied and the return loss performance of each channel is obtained as shown in Table 5.4. This table shows the return loss is lesser for the lesser value of spatial distance between successive channels. The diagonal spacing between two channels is obtained by a spacing of ‘a mm’ in horizontal and vertical directions as shown in Figure 5.13. In general mutual coupling between the channels is directly proportional to the spatial distance between them. The effect of mutual coupling will spoil the return loss performance of phased array RF coil. The phased array coil presented in this work achieves better return loss (>20 dB) in all the channels for the spatial distance value of greater than 11 mm. A return
loss of 20 dB value indicates, from the total input power supplied to the RF coil, 1% of power is reflected back to input side. If spatial distance between neighbouring octagons increases, mutual coupling between successive channels reduces. This increases the return loss value of corresponding RF coil channel as indicated in Table 5.4. The Table 5.5 shows the RF coil dimensions for various values of spatial distance between neighbouring channels.

<table>
<thead>
<tr>
<th>Table 5.4</th>
<th>Return loss variations of phased array RF coil for various spatial distances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel Number</td>
<td>Return Loss for various Spatial distance parameters (dB)</td>
</tr>
<tr>
<td>Channel 1 (-S_{11})</td>
<td>a=6 C=8.4853</td>
</tr>
<tr>
<td>Channel 2 (-S_{22})</td>
<td>17.5</td>
</tr>
<tr>
<td>Channel 3 (-S_{33})</td>
<td>16</td>
</tr>
<tr>
<td>Channel 4 (-S_{44})</td>
<td>13.1</td>
</tr>
<tr>
<td>Channel 5 (-S_{55})</td>
<td>16</td>
</tr>
<tr>
<td>Channel 6 (-S_{66})</td>
<td>12.8</td>
</tr>
<tr>
<td>Channel 7 (-S_{77})</td>
<td>17.5</td>
</tr>
<tr>
<td>Channel 8 (-S_{88})</td>
<td>17.5</td>
</tr>
<tr>
<td>Channel 9 (-S_{88})</td>
<td>12.8</td>
</tr>
<tr>
<td>Channel 10 (-S_{88})</td>
<td>16</td>
</tr>
<tr>
<td>Channel 11 (-S_{88})</td>
<td>13.1</td>
</tr>
<tr>
<td>Channel 12 (-S_{88})</td>
<td>16</td>
</tr>
<tr>
<td>Avg. Return loss</td>
<td>17.5</td>
</tr>
<tr>
<td>Avg. Return loss</td>
<td>15.48</td>
</tr>
</tbody>
</table>
### Table 5.5  12 channel phased array RF coil dimension

<table>
<thead>
<tr>
<th>S. No</th>
<th>Spatial parameters between neighboring channels</th>
<th>12 channel Phased array coil dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a (mm)</td>
<td>C (mm)</td>
</tr>
<tr>
<td>1</td>
<td>6</td>
<td>8.4853</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>9.8995</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>11.3137</td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td>12.7279</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>14.1421</td>
</tr>
</tbody>
</table>

### 5.5 CONCLUSION

A new octagon shaped 12 channel phased array RF surface coil is proposed for human spine imaging needs at 1.5 Tesla. Initially a single channel RF coil design is verified for its return loss and quality factor performance. Afterward the same single channel RF coil is extended for 12 channel phased array construction at 63.87 MHz (1.5 T). In both single channel as well as 12 channel operation return loss value of greater than 20 dB is achieved. This shows the appropriateness of octagon shaped RF coil geometry with optimized matching network for multichannel operation. The solitary factor which controls the performance of multichannel phased array RF coil is the spacing between nearby channels. After investigating the results of 8 mm width 12 channel RF coil, a diagonal spacing of greater than 11.3137 mm gives a higher value of return loss. This gives the total RF coil dimension as 382 mm x 284 mm which is compatible with practical spine RF coil dimensions ranges.