

Chapter 9

Impedance Matching of Power Amplifiers

Introduction

In order to obtain the most power from a bipolar or field effect transistor, the input and output impedances of the device must be matched to that of the circuit in which it is placed. Similarly if an antenna is to be driven effectively, the antenna needs to be matched. For the maximum power transfer, the source impedance and the load impedance must be a conjugate match, that is the resistive parts must be the same and the imaginary parts must be the same magnitude but opposite polarity.

There are three basic types of matching:

Transformer matching: RF Transformers can be used to produce very wideband impedance matching. The main limitations are the restricted range of available impedances (due to the turns-ratios being limited) and the frequency limitations on transformers.

LC matching: where inductors and capacitors are used to effect the impedance transformation. LC matching results in a relatively narrow bandwidth match. LC matching is very practical at frequencies from 30 MHz to 300 MHz. LC matching permits easy tuning of the match to allow for device variations.

Transmission line matching: By using a transmission line of a required length and Characteristic Impedance, the required composite match can be obtained. Such a match tends to be of a broader frequency range than LC matching and can be applied at frequencies above about 150 MHz. It is difficult to tune the length and characteristic impedance of a transmission line once constructed.

For each application, each of the above matching techniques must be evaluated against the design criteria and the most appropriate technique selected.

Choice of Components and Q value

It is very important that the value of capacitors and inductors used be measured at the operating frequency. Many capacitors are not suitable for RF applications, as their self resonance frequency is below the required operating frequency. For power applications, inductors with ferrite cores may not be suitable as their losses may be too high.

For a simple parallel tuned network, like the Pi network, the circulating current in a resonator is approximately Q times the external load current. For a 50 Watt amplifier, driving a 50 Ω load a Q of 10 the current circulating in the Pi network is thus of the order of 10 Amps. This can cause significant heating and failure of the components. For some networks like both the T networks and the Bandpass L network, very high voltages can be experienced at some nodes and this can lead to voltage breakdown of components. The higher the Q the higher the stress on the components. A high Q value can also cause the matching network to drift out of match if the components change due to temperature. In general a Q value as low as possible is desirable, as this will give the widest bandwidth match and the lowest component stress. If the network is to be used as an output matching network of an amplifier and harmonics are to be filtered as well,

a higher Q value should be considered, since the higher the Q, the higher the attenuation at the amplifier harmonics. Since the current and voltage limits in the output matching networks are very important, a trade-off between the Q value and Number for filter sections required to achieve the required harmonic attenuation may need to be considered.

Large Signal Parameters: The large signal input and output impedances and the large signal S parameters are very different from the small signal impedances and small signal S parameters. The large signal parameters should be used in the design.

LC Matching

In LC Matching Inductors and Capacitors are used to obtain the required conjugate impedance match. The equations for calculating the components required are contained in Motorola Application note 267. LC matching is very practical for power amplifiers from 30 to 300 MHz. A good indication of the suitability of LC matching for a transistor is by noting the test circuits used by the manufacturers for the proposed device.

Because it is easy to tune the matching network using variable capacitors, these LC matching networks are normally used by the manufacturers to determine the input and output impedance of the devices. The device is placed in a test jig and the matching network is adjusted to obtain the required output power at a good efficiency and with a low input return loss. The values of the resulting LC matching components are then used to determine the input and output impedance of the device.

AN267 describes 4 matching networks. In all the equations, the device impedance is $R_d + jX_d$ and the load impedance is R_L . This notation is different from AN267, to avoid confusion between R_1 and R_L , particularly is a capital L is used. In the equations it is not assumed that the device is capacitive, so that X_d is used for the reactive part of the device impedance, instead of $-X_{\text{coul}}$. Also in AN267 for the Bandpass T and the Lowpass T networks, different expressions for A and B are used. In these notes consistent expression for A and B are used.

Pi Network

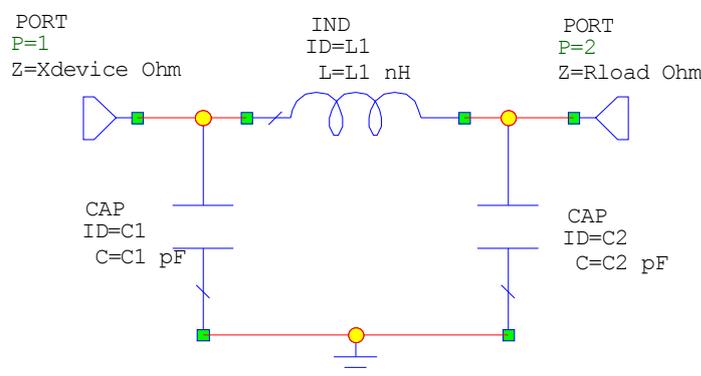


Figure 1. Pi Matching Network.

The Pi matching network is very useful for matching high impedance sources to 50 Ω loads. Pi matching is normally used in valve amplifiers. For high power solid-state devices, the impedance values become impractical with very large capacitors and very small inductors being required. Figure 1 shows the Pi network used for matching.

To obtain the component values, firstly decide on a Q value for the matching network. The Q value will effect the bandwidth, harmonic attenuation and component stress. For the Pi network, the input impedance needs to be a parallel network, so that a series to parallel transformation may need to be applied before the network evaluation as shown in equation 1, which transforms the device impedance of $R_D + jX_D$ into R_P in parallel with X_P . The equations for the Pi network in AN267 assume that the device is resistive and that any reactive impedances are compensated for after the Pi network is designed. This also applies for the Visual Basic program included with these notes. The equations in the included MWO files handle reactive parts correctly. The complete equations for the Pi matching network are as follows:

$$R_p = \frac{R_D^2 + X_D^2}{R_D} \quad X_p = \frac{R_D^2 + X_D^2}{X_D} \quad \text{Eqn. 1}$$

$$Y_{C1} = \frac{1}{X_{C1}} = \frac{Q}{R_p} + \frac{1}{X_p} \quad \text{Eqn. 2}$$

$$X_{C2} = R_L \sqrt{\frac{\frac{R_p}{R_L}}{(Q^2 + 1) - \frac{R_p}{R_L}}} \quad \text{Eqn. 3}$$

$$X_L = \frac{QR_p + (\frac{R_p R_L}{X_{C2}})}{Q^2 + 1} \quad \text{Eqn. 4}$$

Note that $Q^2 + 1$ must be larger than R_p/R_L for X_{C2} to be valid.

Low Pass T Network

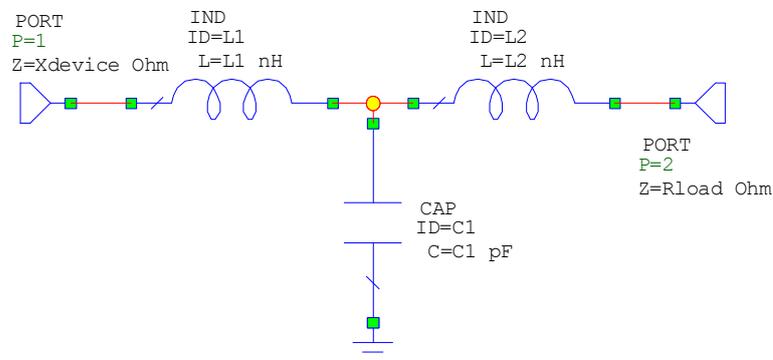


Figure 2. T Matching Network.

The Low pass T network is very good for use as an output matching network for a power amplifier stage, where the amplifier is to be connected to an antenna. Having a

series inductor (L1) as the element connected to the device results in an open circuit to the second harmonic currents, resulting in a reduced current flow through the transistor and resulting in a higher efficiency. However since the output voltage is more distorted a higher inter-modulation distortion may result. For more severe filtering of harmonics, a cascaded set of low pass matching networks is desirable.

The equations for the low pass T network are as follows:

$$X_{L1} = QR_D - X_D \quad \text{where } R_D + jX_D \text{ is the device impedance} \quad \text{Eqn. 5}$$

$$X_{L2} = R_L A \quad \text{Eqn. 6}$$

$$X_{C1} = \frac{B}{Q + A} \quad \text{Eqn. 7}$$

where

$$A = \sqrt{\left[\frac{R_D(1+Q^2)}{R_L} \right]} - 1 = \sqrt{\left[\frac{B}{R_L} \right]} - 1 \quad \text{Eqn. 8}$$

$$B = R_D(1+Q^2) \quad \text{Eqn. 9}$$

Note this network clearly shows that the Q used in the matching network relates to the impedance transformation ratio. The minimum Q occurs when $A_1=0$, so that

$$Q_{\min} = \sqrt{\frac{R_L}{R_D} - 1} \quad \text{Eqn. 10}$$

Bandpass L network

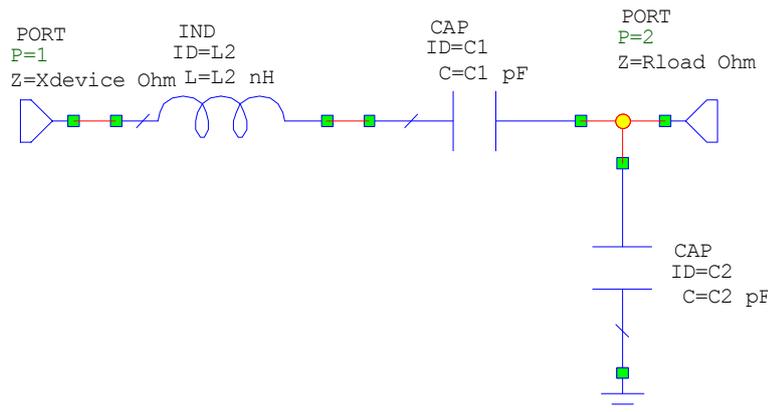


Figure 3. Bandpass L Matching Network.

The bandpass L network is often used as test circuit by semiconductor manufacturers. It has a DC block, to allow biasing to be set up for the input of transistors and to prevent any DC supply from appearing on the output of an amplifier stage. Normally C1 and C2 are adjustable, making it very easy to tune the amplifier for either a peak of output for an output matching network or for the best input match for an input matching network.

The equations for the band pass L network are as follows:

$$X_{C1} = QR_D \quad \text{where } R_D + jX_D \text{ is the device impedance} \quad \text{Eqn. 11}$$

$$X_{C2} = R_L \sqrt{\frac{R_d}{R_L - R_d}} \quad \text{Eqn. 12}$$

$$X_{L2} = X_{C1} + \left(\frac{R_D R_L}{X_{C2}} \right) \quad \text{Eqn. 13}$$

The device Reactance X_D is incorporated in either C_2 for capacitive device impedances or into L_2 for inductive device impedances. This will ensure the lowest Q of the network and thus the widest bandwidth. This network can only be used if $R_D < R_L$, since the parts under the square root sign

Bandpass T network

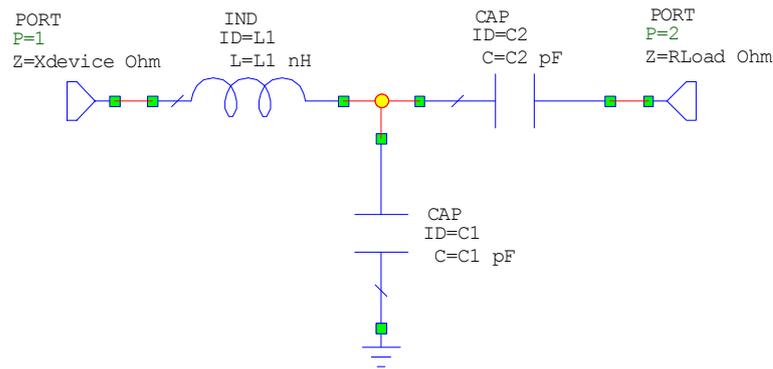


Figure 4. Bandpass T Matching Network.

The equations for the band pass T network are as follows:

$$X_{L1} = QR_D - X_D \quad \text{where } R_D + jX_D \text{ is the device impedance} \quad \text{Eqn. 14}$$

$$X_{C2} = A R_L \quad \text{Eqn. 15}$$

$$X_{C1} = \frac{B}{Q - A} \quad \text{Eqn. 16}$$

Where A and B and the minimum Q are as before:

$$B = R_D(1 + Q^2) \quad A = \sqrt{\left[\frac{R_D(1 + Q^2)}{R_L} \right] - 1} = \sqrt{\left[\frac{B}{R_L} \right] - 1} \quad \text{Eqn. 17}$$

This network can only be used if $R_D < R_L$, since otherwise negative values for C_1 result.

Important notes:

- 1 Some of the equations for the Pi network are different since the reactive parts of the device are handled in the equations presented here, while they are not in AN267 or the Visual Basic program included under the "Resources" for this course.
- 2 In these notes A and B are kept the same in these notes, while A and B are swapped and changed in AN267.
- 3 In AN267 the term A for the Bandpass T is wrong. AN267 uses:

$$A_{267} = \sqrt{\left[\frac{R_D(1+Q^2)}{R_L} \right]} - 1 = \sqrt{\left[\frac{B}{R_L} \right]} - 1 \quad \text{Eqn. 18}$$

That will not give a correct match, as can be verified by using Microwave Office. The square root should be extended to cover the -1 term as in the expression for A in equation 17.

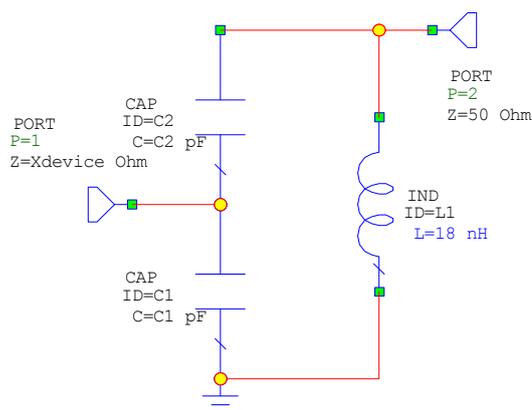
Capacitive Impedance Transformer

Figure 5. Capacitive Impedance Transformer Matching Network.

The capacitive transformer is not included in AN267, but this network can be quite useful and give very realisable components in inter-stage matching networks. The network is thus used to match the output impedance of one transistor to the input impedance of another transistor. The circuit is related to the Lowpass Pi network, except the ground and the input port are changed. For this network the output impedance at port 2 is always larger than that at port 1.

For a non-reactive device, the equations for the component values are the same as those for the Pi network, with the input impedance being the same (at port 1), but the reference impedance 50Ω now being the same as $(R_1 - R_{\text{device}})$ used in the Pi network. So instead of R_1 , the value $R_1 - R_{\text{device}}$ is used in the equations. The values can also easily be obtained using computer optimisation, as was done in the example below. The calculations for the Capacitive Transformer in the included MWO file, handles the reactive part by using the equations for a resistive device and then tuning C2 and L1 to obtain a correct match.

Example

The above equations will now be applied to an MRF1535, 35 Watt LDMOS FET in order to obtain a suitable match. This FET is suitable for operation from 135 MHz to 520 MHz and can thus be used for mobile radio applications. An amplifier at 150 MHz is required.

To calculate the components, equations 1 to 18 must be evaluated. The author wrote a Visual Basic program, which is included under the "Resources" section of these notes. For a Pi network, AN267 did not include the device reactance as part of C1. The Visual Basic program follows this practice as it is easy to manually include any device capacitance as part of C1 and produce the lowers Q in the process. With the current MWO software, it is easier to include the equations 1 to 18 as part of the "Global Variables" and this has been done for the production of figures 9 to 18. The resulting MWO file is included as part of these lectures.

Using the manufacturers data, the input impedance at the required frequency is determined. It should be noted that these values do depend on individual device and the quiescent current, so that in practice the actual values may be slightly different. For this device the input impedance is the same at 137 MHz and 155 MHz, and is $5 + j0.9 \Omega$. The $j0.9 \Omega$ reactance corresponds to a 955 pH inductor at 150 MHz.

The Q value to be selected for the matching network is a compromise. For a wide bandwidth a low Q is required. However the desired matching may not be possible at low Q values. For this FET only the bandpass L and Pi network are possible for matching with Q values below $Q = 3$. This is shown in figure 7 for a Q value of 2.5. The Pi network requires a 8.17 nH inductor, which is a fraction small to make reliably.

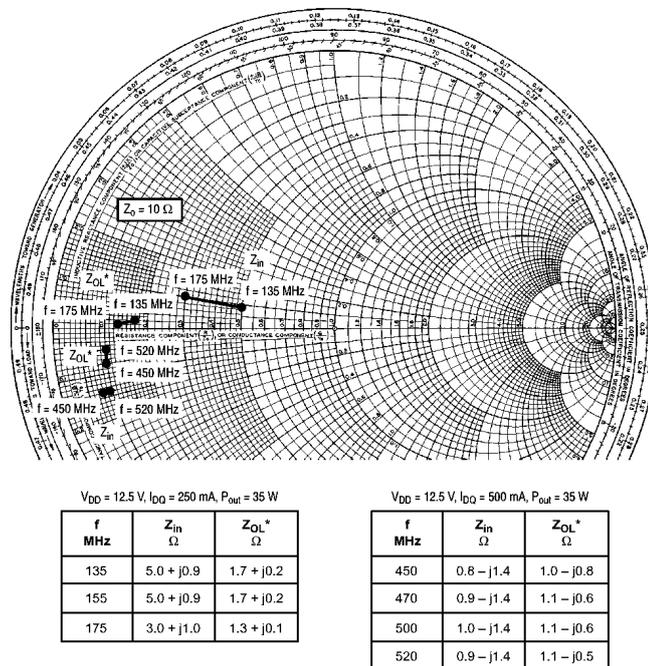


Figure 6. Part of Datasheet showing large signal Input and Output impedances.

For matching into a 50Ω load, the minimum Q for both T networks is 3. The designs below use a Q of 3.5, which is sufficiently high to be able to have all matching networks, so that they can be compared and is sufficiently low to have as wide a bandwidth as possible. Figures 8 to 18 show that the bandwidth over which a good

match is obtained is relatively small compared with transformer matching and transmission line matching.

A Visual Basic program incorporating the matching equations for the different networks is included in the "Resources" for this course and can be used to perform the calculations as shown below. This allows Q values to be varied easily to ensure the network uses practical components. As mentioned before, figure 8 does not fully compensate for the reactive part of the source impedance for the Pi network. For this example with $Z_d=5+j0.9$ and $Q=3.5$, figure 8 evaluates C_1 as 755.25 pF while the correct value as calculated by the equations in the included MWO file is 756.41 pF.

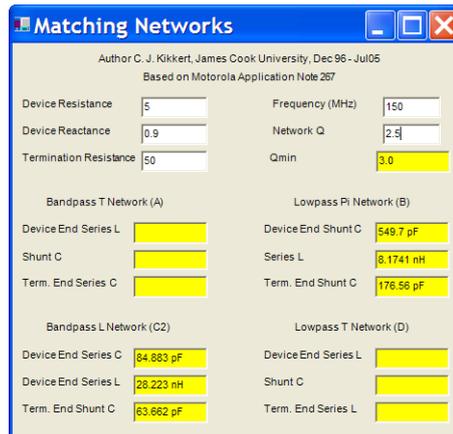


Figure 7. Input Matching component values for a MRF1532 FET, Q=2.5.

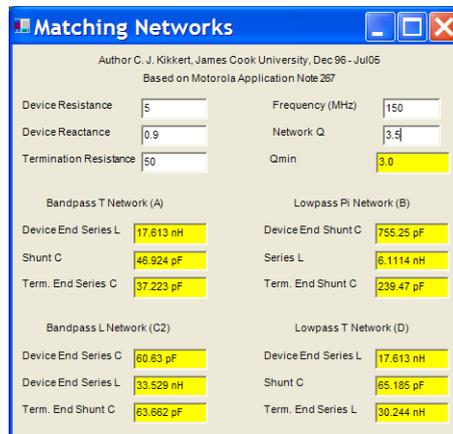


Figure 8. Input Matching component values for a MRF1532 FET, Q=3.5

The matching components are incorporated in a computer simulation package, like Microwave Office, as shown below. In order to have a source impedance of $5 + j0.9 \Omega$, a voltage controlled voltage source with a zero output impedance is used. This is then followed by a network representing the input impedance of the FET. It is however possible make the impedance of port 1 to be the resistive part of the device impedance. The transfer function then will have always have an insertion loss rather than the gain as indicated in the following figures. A passive network cannot have a power gain. The power gain is provided here by the voltage dependent source. For figures 9 to 18, impedance matching with a $Q = 3.5$ as indicated in figure 8 is used.

Pi network

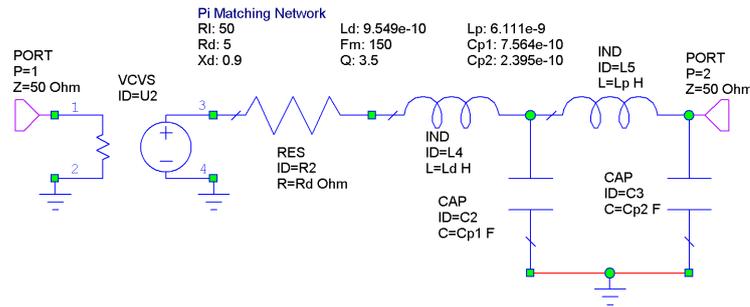


Figure 9. Circuit representation of the input impedance and the matching network.

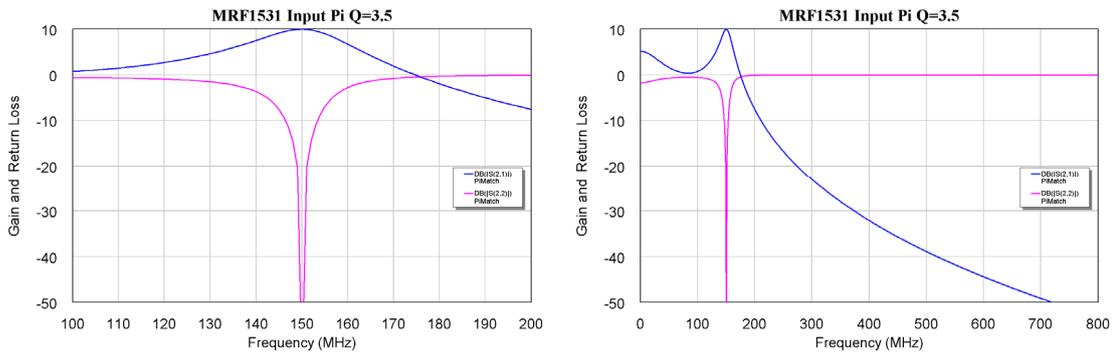


Figure 10. Frequency Response of the Pi Matching Network

Lowpass T network

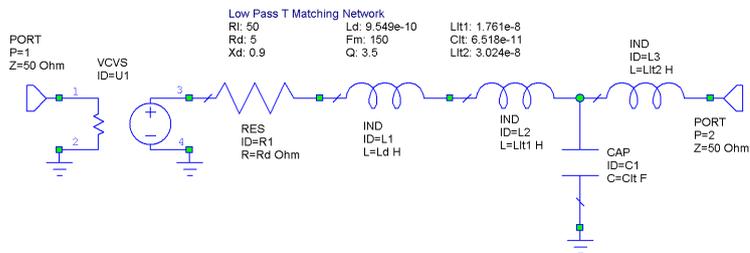


Figure 11. Circuit representation of the input impedance and the matching network.

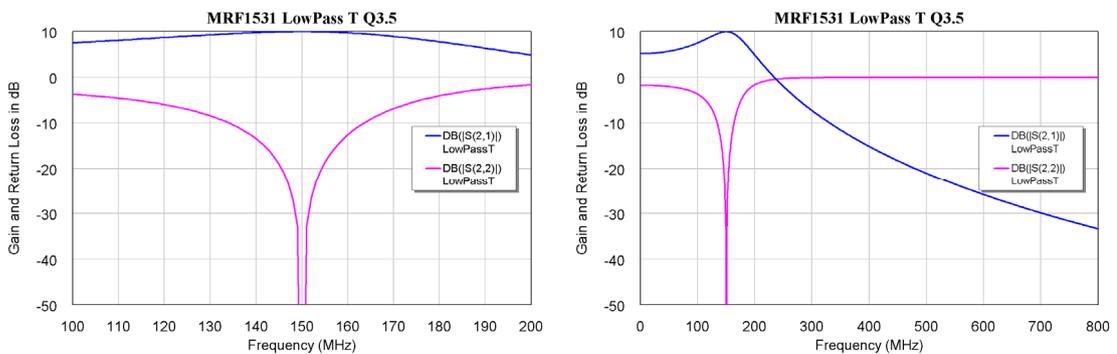


Figure 12. Frequency Response of the Lowpass T Matching Network

Bandpass T network

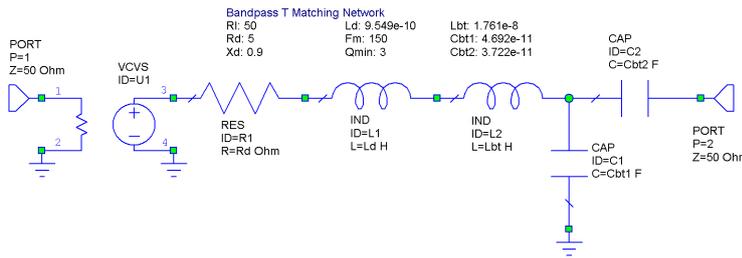


Figure 13. Circuit representation of the input impedance and the matching network.

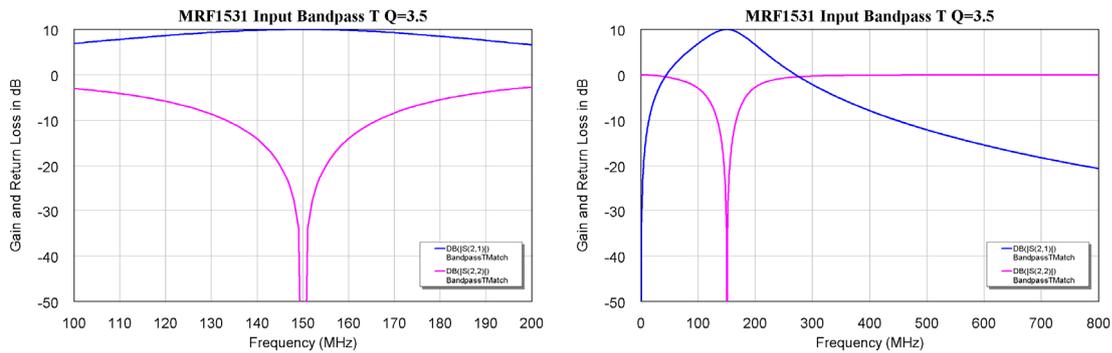


Figure 14. Frequency Response of the Bandpass T Matching Network (Harmonic View)

BandPass L Network

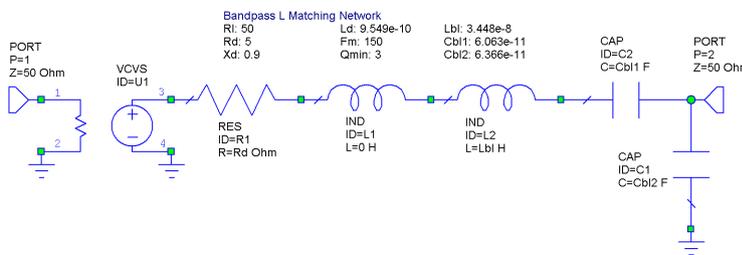


Figure 15. Circuit representation of the input impedance and the matching network.

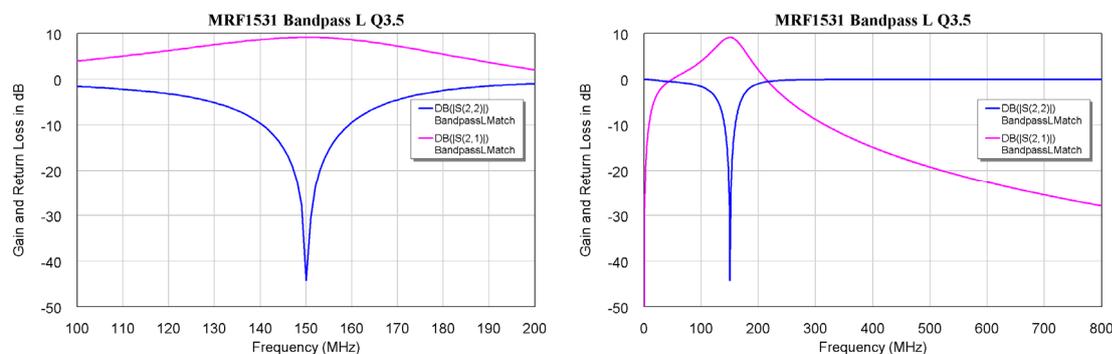


Figure 16. Frequency Response of the Bandpass L Matching Network

Capacitive Transformer Resonator

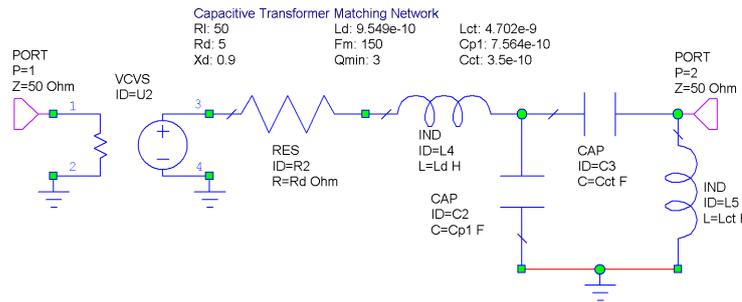


Figure 17. Circuit representation of the input impedance and the matching network.

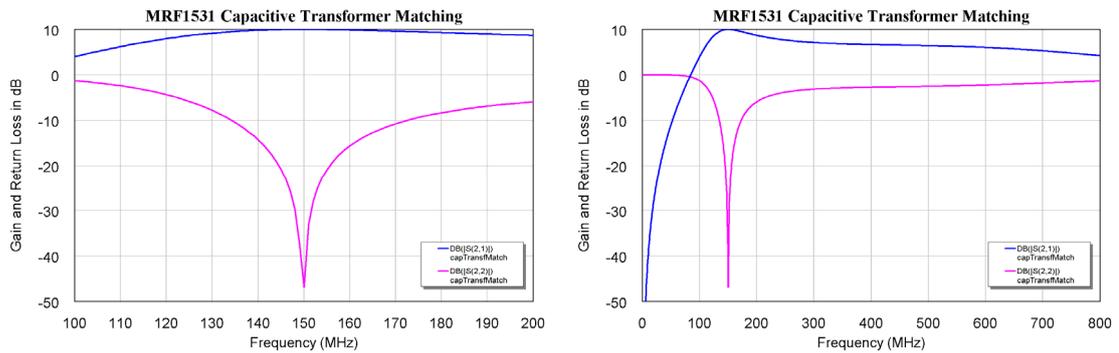


Figure 18. Frequency Response of the Bandpass L Matching Network.

Comparing figures 9 to 18, shows that for the equations 1 to 18, the Pi matching network has the lowest bandwidth, but its Q can be adjusted to make the bandwidth comparable to the other networks.

Transformer matching

In transformer matching, an RF transformer, as described in Chapter 3 of these notes is used to provide the impedance transformation required. Since the number of turns used must be an integer and the impedance transformation is the turns ratio squared, the impedance transformation ratios are limited to the square of simple fractions. For the matching of the FET in this example, a $5 + j0.9 \Omega$ impedance is required. This can best be approximated by a 3:1 turns ratio transformer, giving a 9:1 impedance transformation, so that a 50Ω source is transformed into a 5.55Ω impedance, which is sufficiently close to $5 + j0.9 \Omega$ for most of the power to be transferred effectively. If needed, the reactive part can be resonated out, using a $-j0.9 \Omega$ reactive impedance in series.

Transformer matching provides a very wideband match, of typically three decades (1000:1 frequency range) if the impedance of the device to be matched does not change. In practice the device impedance changes significantly over such a frequency range, thus limiting the effective frequency range for the matching. FET amplifiers that are well matched up to 100 MHz can easily be designed, as is evident from many power FET manufacturers application notes.

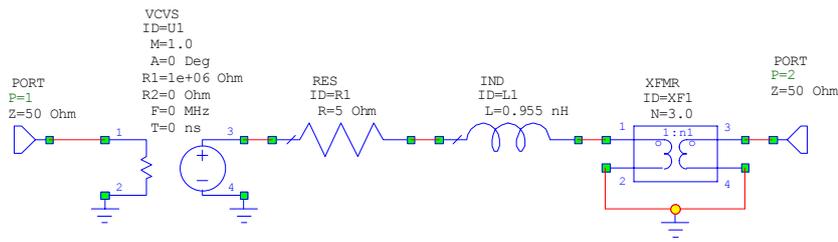


Figure 19. Circuit representation of the input impedance and the matching network.

By adding a 23.7 pF capacitance across pin 1 and 2 of the transformer, the match can be extended as shown in the right graph of figure 20. The value of the capacitance required is best determined experimentally.

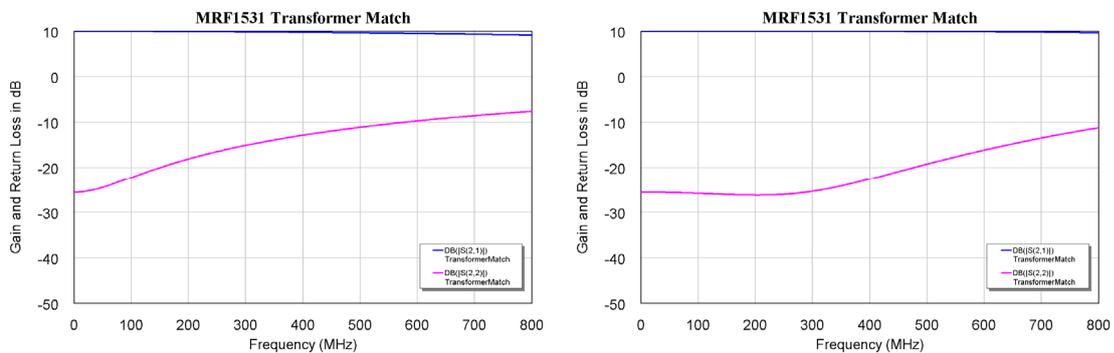
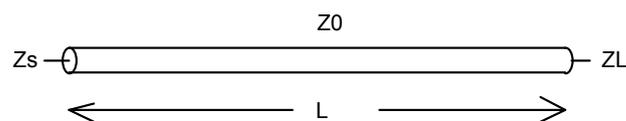


Figure 20. Frequency Response of Transformer Match (Left) and the Optimised Transformer Match (Right).

Transmission Line Matching

For a transmission line of characteristic impedance Z_0 and length L , the



The impedance looking into a transmission line that is terminated in a load Z_L is:

$$Z_s = Z_0 \frac{Z_L + jZ_0 \tan(\beta l)}{Z_0 + jZ_L \tan(\beta l)} \tag{Eqn. 19}$$

By substituting $Z_s=R_s+jX_s$ and $Z_L=R_L+jX_L$ and then solving for Z_0 and the transmission line length θ as an electrical length, one obtains the following equations:

$$Z_0 = \sqrt{\frac{R_s |Z_L|^2 - R_L |Z_s|^2}{R_L - R_s}} \tag{Eqn. 20}$$

$$\theta = \text{Arc tan} \left(\frac{Z_0 (R_s - R_L)}{R_s X_L + R_L X_s} \right) \tag{Eqn. 21}$$

This assumes that Z_0 is real and $\tan(\beta l)$ is real. These equations do not always give a match, but if no match is possible, shifting the impedance by using a short length of transmission line will always result in a match. A simple visual basic program TlineMatch, can be used to evaluate the equations above. This program is included with the resources for this course. This program gives $Z_0 = 15.78\Omega$ and $\theta = 86.37$ degrees.

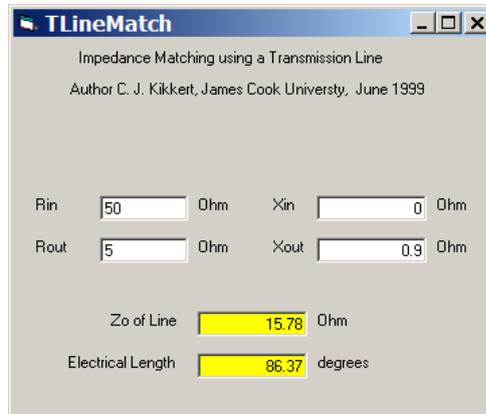


Figure 21. Tline Match Panel

Those line parameters can now be used in Microwave Office to simulate the matching performance.

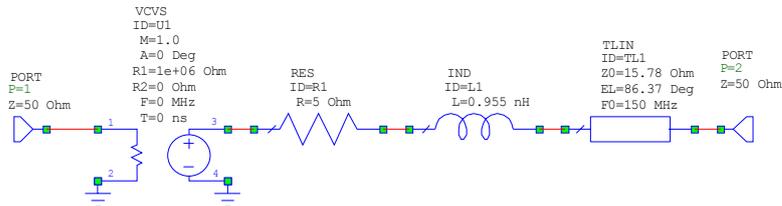


Figure 22. Circuit representation of the input impedance and the matching network.

From figure 23, it can be seen that transmission line matching gives a very broad band impedance match. The only limitation is that the line lengths can physically become too large. This is why this technique is predominantly used above 100 MHz. Transmission lines can also replace the inductors used in the LC matching, for networks like the T network, and such networks are commonly used above 100 MHz.

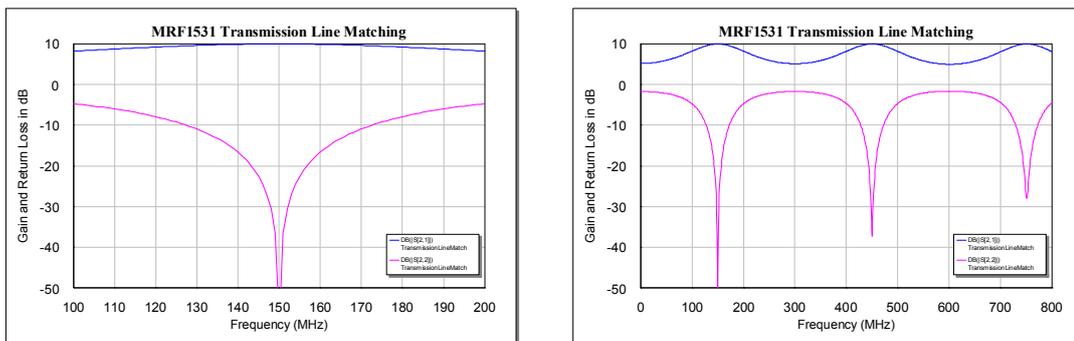


Figure 23. Frequency Response of the Transformer Match.

Broadband Matching

Sometimes a wideband match is required. This can either be a wideband match into an active device, or a simple impedance transformation. If a wideband match into an active device is required, then the either the device impedance must be able to be accurately represented by a simple circuit, ie resistor and capacitor or inductor or one must use the large signal S parameter data as a data table in Microwave office. The matching network is then designed. The design can use broadband matching equations published by Motorola in as a succession of simple matching networks. As an example consider an impedance transformation from 50 ohm to 1.85 ohm. The impedance transformation ratio is 27 to one and this is achieved by cascading three pi networks with impedance transformations of 3 to one. The impedance levels are thus 50Ω, 16.67 Ω, 5.55Ω and 1.85Ω. The match is required for the 250MHz to 500MHz range. The individual impedance match calculations are done at a centre frequency of 353 MHz, the geometric mean of 250MHz and 500MHz.

To get the broadest match, a low Q is used. A Q of 0.4 will give realisable components for the pi network.

Author C. J. Kikkert, James Cook University, Dec 96 - Jul 05
Based on Motorola Application Note 267

Device Resistance	5	Frequency (MHz)	150
Device Reactance	0.9	Network Q	3.5
Termination Resistance	50	Qmin	3.0

Bandpass T Network (A)		Lowpass Pi Network (B)	
Device End Series L	17.613 nH	Device End Shunt C	755.25 pF
Shunt C	46.924 pF	Series L	6.1114 nH
Term. End Series C	37.223 pF	Term. End Shunt C	239.47 pF

Bandpass L Network (C2)		Lowpass T Network (D)	
Device End Series C	60.63 pF	Device End Series L	17.613 nH
Device End Series L	33.529 nH	Shunt C	65.185 pF
Term. End Shunt C	63.662 pF	Term. End Series L	30.244 nH

Figure 24. Component calculation for the first element.

Repeating the component calculation using the same Q and centre frequency for the other elements results in the circuit diagram below. All the elements are made optimisable and the network is entered into computer simulation software like Microwave Office. If the calculations are done correctly, a good starting match results as shown in figures 24 and 25.

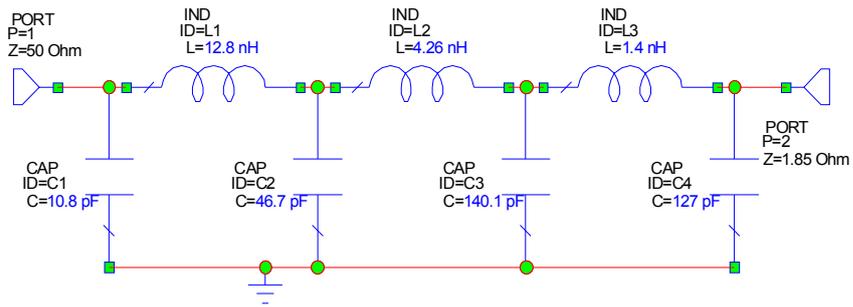


Figure 25. Starting Broadband Match Schematic

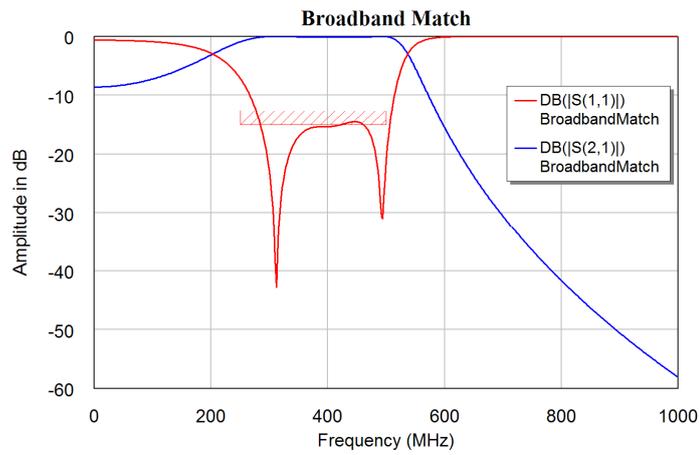


Figure 26. Starting Broadband Match Input Impedance.

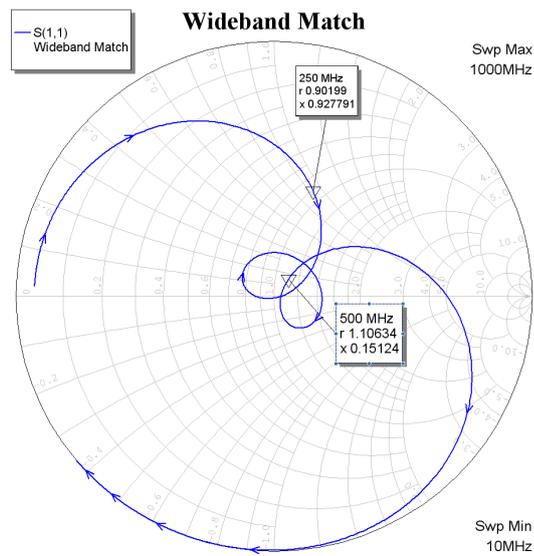


Figure 27. Starting Broadband Match Input Impedance.

The impedance match does not quite meet the required 250 MHz to 500 MHz bandwidth, so the network is optimised to meet the specification of having S_{11} to be less than -15 dB.

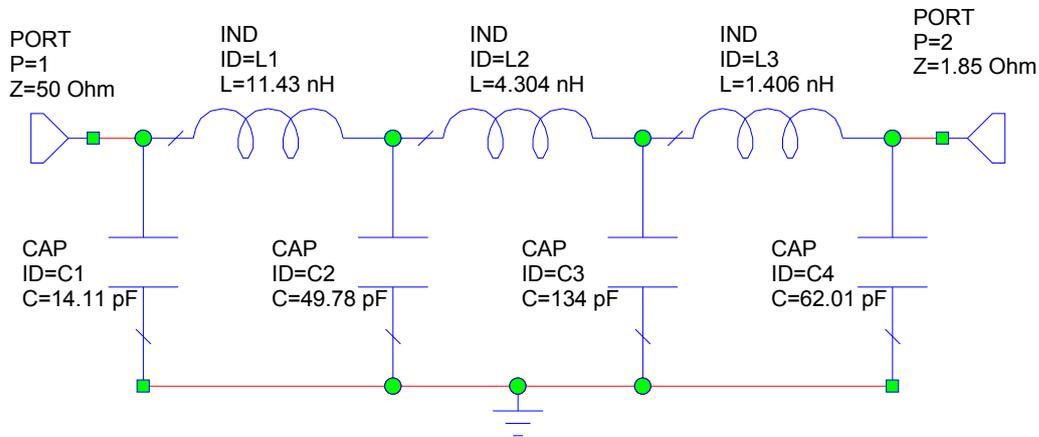


Figure 28. Final Broadband Match Schematic

The optimisation produces the matching network shown in figure 28. The biggest change in component value is that of the device end (port2) where the 127 pf starting capacitance has become 62 pf. The frequency response is shown in figure 29. It can be seen that S_{11} is now less than -15 dB for the entire 250 – 500 MHz frequency range. Figure 30 shows the Smith chart of the network after optimisation. It can be seen that a good match is obtained.

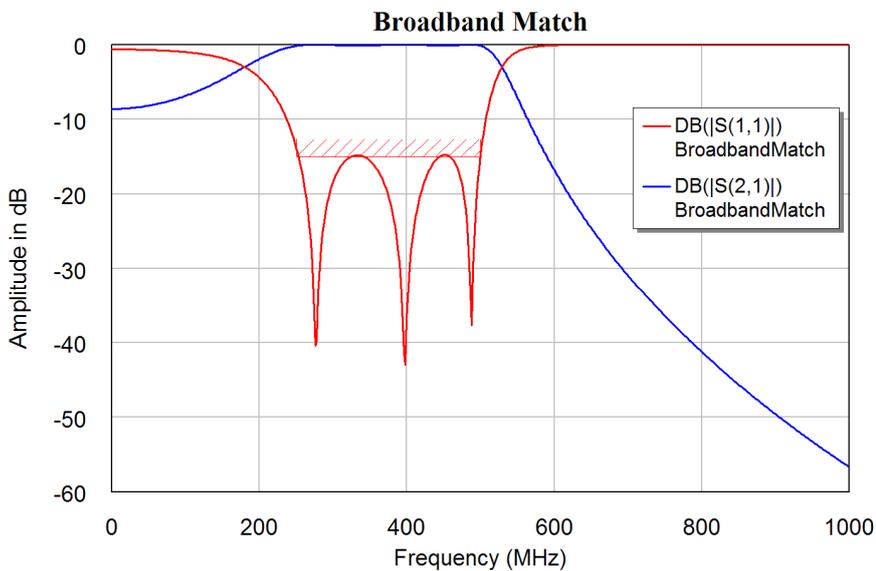


Figure 29. Final Broadband Match Input Impedance.

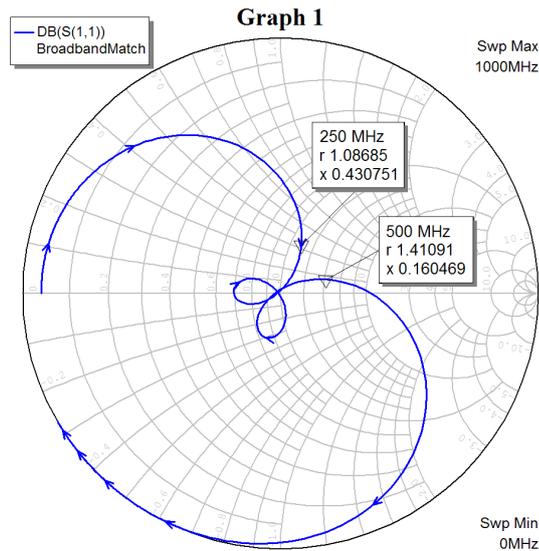


Figure 30. Final Broadband Match Input Impedance.

Broadband Amplifier

Applying broadband matching to a transistor or FET results in additional problems in that since the device is not normally unilateral, there is an interaction between the input and output matching. As an example consider the MRF 1535 transistor that we used before for the impedance matching. From the manufacturer’s data sheet, the S parameters at a drain current of 2 Amp is as follows:

```
!MRF 1535, 12.5V 35W transistor
# MHZ S MA R 50
!F      S11      Ang      S21      Ang      S12      Ang      S22      Ang
!MHz    |S11|      Ang    |S21|    Ang    |S12|    Ang    |S22|    Ang
50      0.94     -176   9.42     88     0.005    -72     0.89     -177
100     0.94     -178   4.56     82     0.005     4       0.89     -177
150     0.94     -178   2.99     78     0.003     7       0.89     -177
200     0.94     -178   2.14     74     0.005    17      0.90     -176
250     0.95     -178   1.67     71     0.004    40      0.90     -175
300     0.95     -178   1.32     67     0.007    35      0.91     -175
350     0.95     -178   1.08     67     0.005    57      0.92     -174
400     0.96     -178   0.93     63     0.003    50      0.93     -173
450     0.96     -178   0.78     62     0.007    68      0.93     -173
500     0.96     -177   0.68     61     0.004    99      0.94     -173
550     0.97     -177   0.59     58     0.008    78      0.93     -175
600     0.97     -178   0.51     57     0.009    92      0.92     -174
```

The lines beginning with ! are comments and have been added for clarity. The line

MHZ S MA R 50

indicates that the frequency in the following file is in MHz, it is an S parameter file and the values are magnitude (rather than dB) and the reference impedance is 50 ohm.

This can now be used as a sub-circuit in Microwave Office. For this example a match from 250MHz to 500MHz is required. An input matching network of the form shown in figure 1 is required. The initial component values are calculated at the centre of the desired frequency range, using a cascaded section of bandpass T and lowpass T

sections, with a progressive impedance transformation. Similarly an output matching network consisting of lowpass T and Pi sections is produced. These networks are then connected to the large signal S parameter model of the transistor. The resulting network is optimised for a good input and output match over the 250 to 500 MHz range. The circuit after optimisation is shown in figure 31

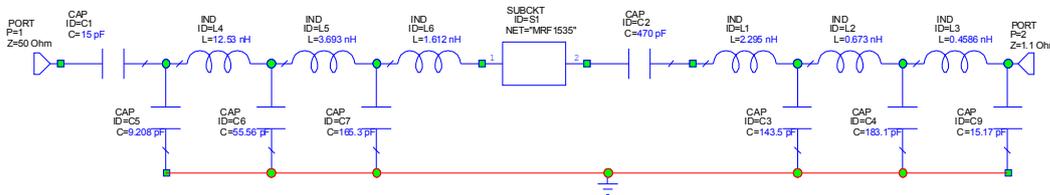


Figure 31. Optimised Broadband Amplifier Matching Network

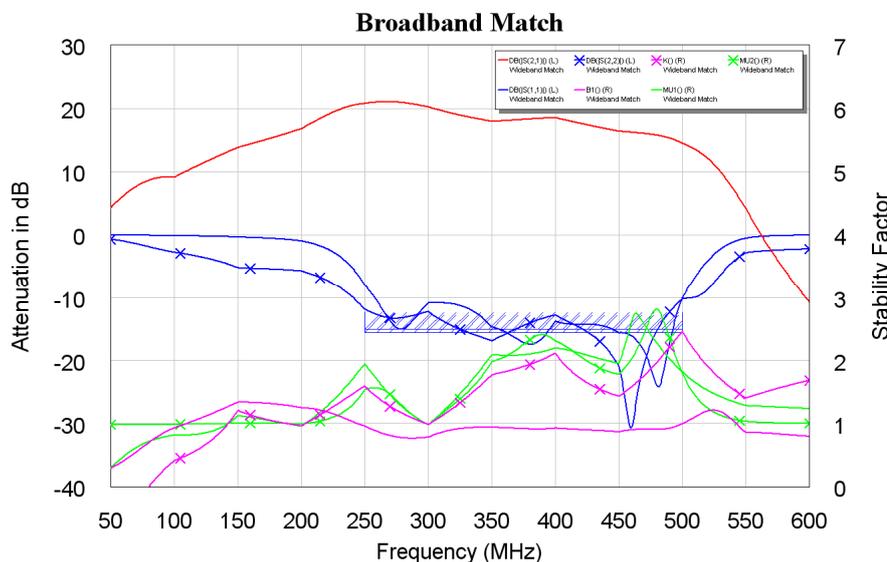


Figure 32. Performance of Broadband Amplifier

Figure 32 shows the performance of the optimised amplifier, it can be seen that a good input and output match is obtained and that this results in a close to 20 dB gain over the entire 250 to 500MHz band. There are however some problems. For unconditional stability, K must be greater than one and B1 must be greater than zero or the input and output μ coefficients must be greater than one. This is the case in the 250 to 500 MHz frequency band, but is no the case outside this region, particularly in the 50 to 100MHz frequency range.

Figure 33 shows the Smith chart indicating the input and output impedances of the whole amplifier as well as the input and output impedances of the FET. Note from the diagram how the parameters change at 50 MHz intervals. That is related to the 50 MHz measuring interval of the S parameters.

In a commercial design, further optimisation and circuit modification may be required to provide a flatter gain characteristic by providing a slight impedance mismatch and changing the optimisation parameters in accordance. In addition steps need to be taken to ensure that the amplifier does not oscillate in the 50 to 100 MHz frequency range.

Stabilisation may be obtained by using resistors, which are only effective at low frequencies, by decoupling them using series inductors. As can be seen here since the FET has a very high gain at low frequency, the amplifier will tend to oscillate at low frequencies.

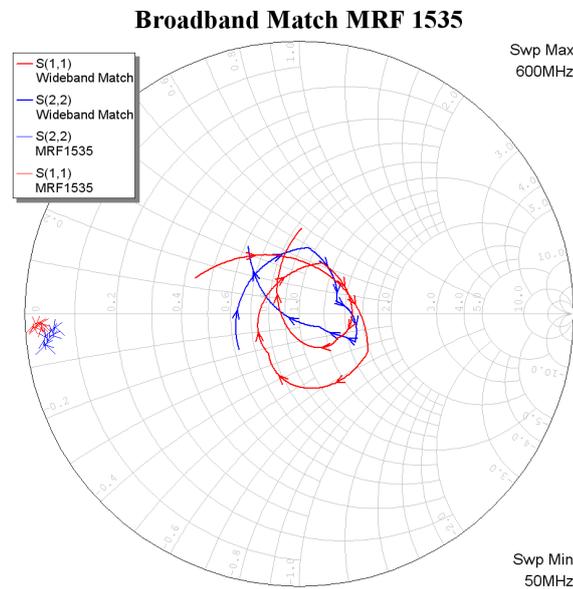


Figure 33. Impedance Match of Broadband Amplifier

In many cases the matching networks are more complex than what has been described here. As an example figure 34 shows the circuit for an MRF 9060 amplifier 60 Watt amplifier operating in the 900 to 1000 MHz frequency region. This is one of the examples from Microwave Office and is similar to sample designs done by Motorola. FET's are more linear than transistors and are thus preferred for applications requiring a low intermodulation distortion, as is required in mobile radio base-station amplifiers. FET's have very high gains at low frequencies and are thus more susceptible to instability. During the last few years, the number of available RF devices has reduced significantly, particularly devices operating below 800 MHz.

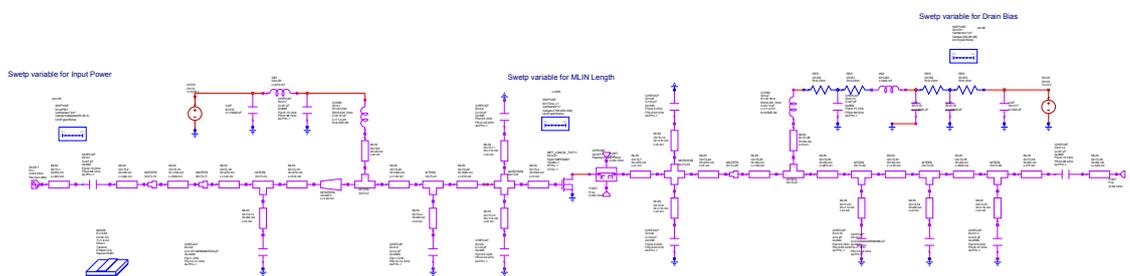


Figure 34. 60 Watt 900 MHz FET amplifier.

Figure 35 shows the layout of this amplifier. The impedance required for the transmission lines for the input matching is very low, since the input impedance is very low. High quality RF capacitors must be used to ensure that the losses in the capacitors

are not excessive. The frequency characteristic of those capacitors, taking the self resonance into account, is included in the analysis. For further details see the MWO, “Motorola LDMOS swept variables” example in the amplifier section of the MWO examples. When doing a power amplifier design it is essential to look at the sample designs produced by the manufacturer for the transistor to be used.

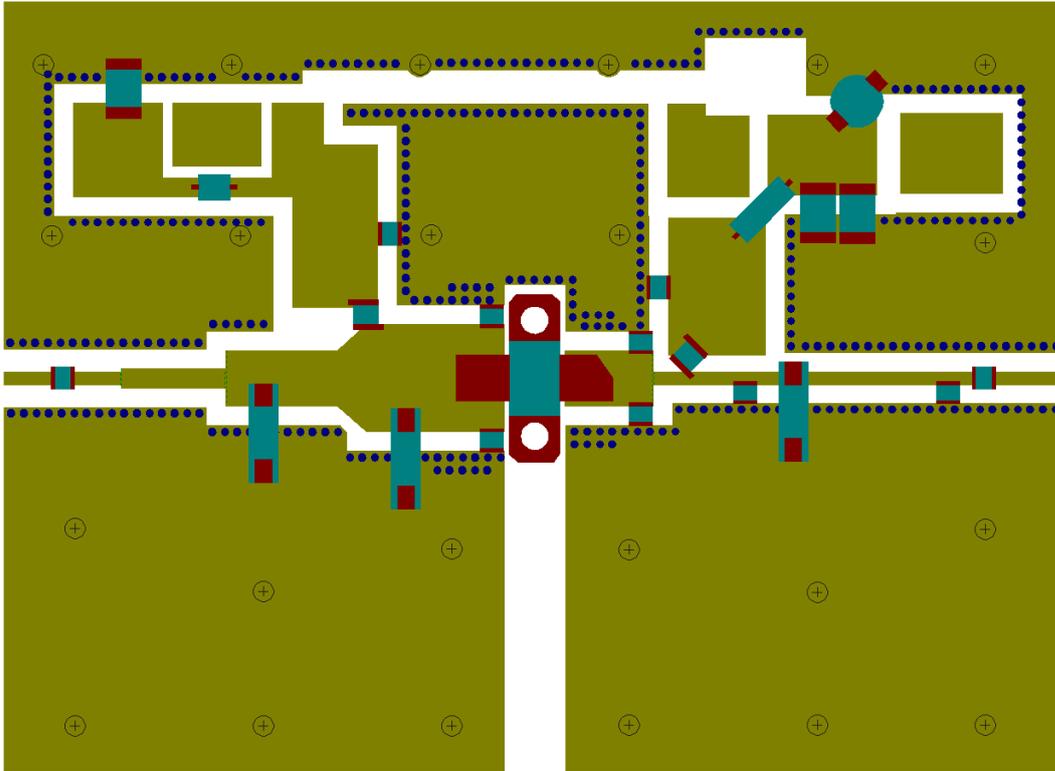


Figure 35. 60 Watt 900 MHz FET amplifier layout.