ASH Transceiver Antenna Impedance Matching

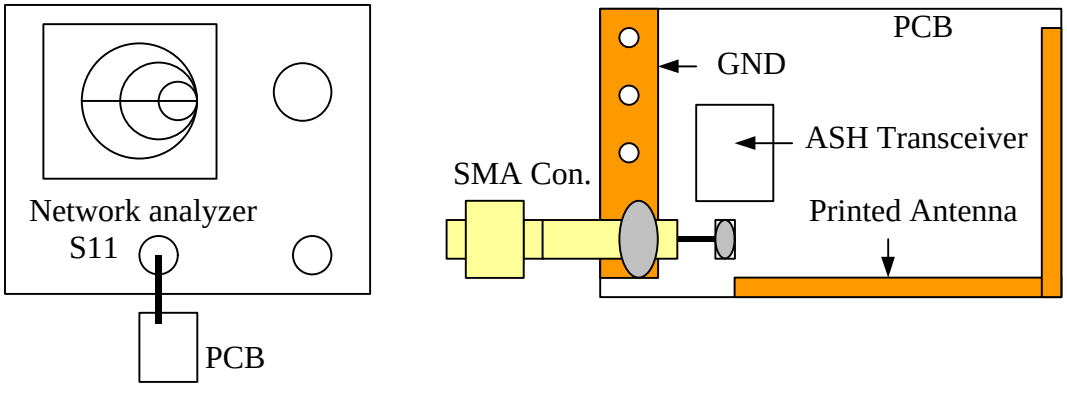
In many low power radio applications, a small physical form factor is required (i.e., a RKE transmitter). In such applications a full sized quarter wavelength antenna becomes impractical; the antenna must be shorter. Short antennas usually present a capacitive load, with the real part of the antenna impedance less than 50 ohms. If such an antenna is connected to the ASH transceiver using the tuning inductor values for a 50 ohm load (given in the data sheet), the antenna will be miss-matched to the ASH transceiver. The result will be reduced transmission range. In order to get the best range with a short antenna, the antenna must be tuned to provide the correct impedance match. This application note discusses the methods to tune a short antenna and sites several examples.

1. Check the antenna impedance

Before starting to tune the antenna, it is necessary to check the antenna impedance. A network analyzer is usually used for antenna impedance measurements and matching.

a. **Preparation for calibration:** Solder a "pigtail" (a SMA connector with a piece of coaxial cable) to the test PCB. Keep the coaxial cable very short. If a long cable is necessary, you can add ferrite beads to the cable to prevent it from radiating. Keep the test antenna away from the cable and the network analyzer to reduce field reflections. At this point the antenna should be disconnected from the transceiver, and the center conductor of the cable should not be connected to the antenna or the transceiver. See Fig. 2(b). The other simple way is to first calibrate just the pigtail without the PCB.

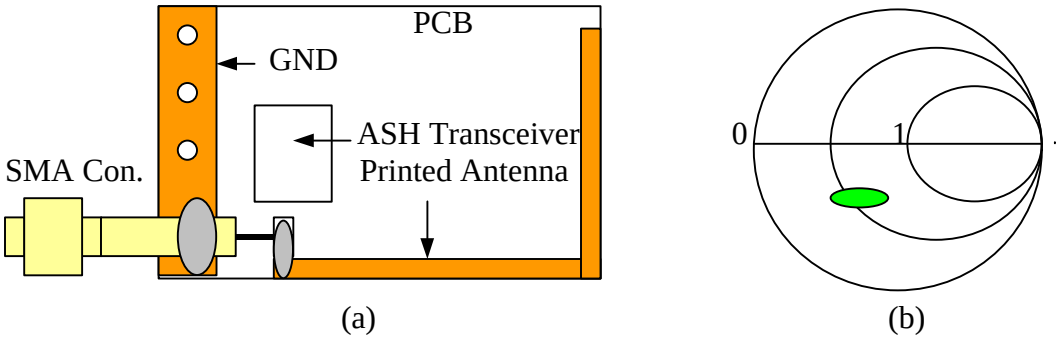
b. **Calibration:** Set the network analyzer to the Smith Chart display (of S_{11}) and set the sweep center frequency to the operating frequency of the ASH transceiver. Connect the SMA connector with the coaxial cable and the PCB to the network analyzer (see Fig. 1(a)) and calibrate for an "open". Then connect the coaxial cable center conductor to the shield and calibrate for a "short". Connect a 50 ohm resistor from the coaxial cable center conductor to GND for "load" and then "done". It is then best to recheck the calibration result for "open and "short" again.



(a) (b)

Fig. 1

c. **Check the antenna impedance:** Solder the central conductor of the coaxial cable pigtail to the test antenna. See Fig. 2(a). Check the antenna impedance with the network analyzer. Normally, the impedance of a short antenna will be lower than 50 ohms and it will be capacitive. The antenna impedance will appear somewhere on the lower half of the Smith chart. See Fig. 2(b).



(a) (b)

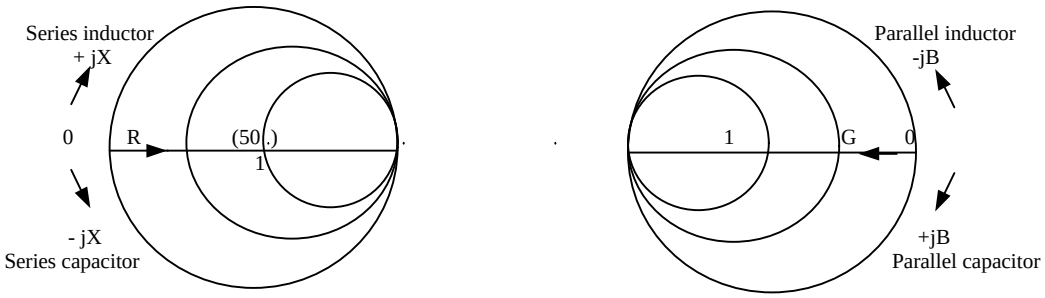
Fig. 2

2. Use Smith Chart and Admittance Chart for Antenna Tuning

The normal way to tune the antenna is by adding series or parallel inductors and/or capacitors. The Smith chart and Admittance chart can help you to determine the tuning method.

The Smith chart is useful for the series tuning components. On the Smith chart, the impedance is increased from 0 to ∞ along with the horizontal diameter from the left to the right. The center is 50 ohms. Adding a series inductor will move the impedance point clockwise, and adding a series capacitor will move the impedance counterclockwise (Fig. 3 (a)).

The Admittance chart is useful for the parallel parts. Adding a shunt inductor will move the impedance counterclockwise; adding a shunt capacitor will move in the clockwise direction (Fig. 3 (b)).



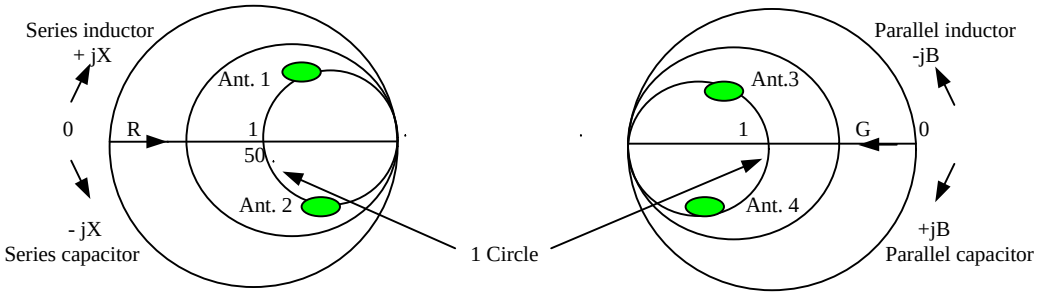
(a) Smith Chart (b) Admittance Chart

Fig. 3

2. Antenna Tuning Example

1). Special Examples for Printed Antennas

If you are lucky, the antenna characteristic impedance will be located on (or very close to) the 1 circle on the Smith chart or Admittance chart (see Fig. 4), where the tuning will be very easy.



(a). (b).

Fig. 4

The Fig. 4(a) shows the impedance of Ant. 1 and Ant. 2, where they are located on the "1" or unity (50 ohm reference) circle of the Smith chart. The Fig. 4(b) shows the impedance of Ant. 3 and Ant. 4, located on the 1 circle of the Admittance chart. Since all of the antennas are located on the 1 circle, tuning the impedance to 50 ohms can be done with only one component.

a. Tuning Antenna 1: It is located on the up half on the 1 circle of the Smith chart as an inductive load. (the inductance value can be read from the top right corner of the network analyzer). Move it to the center with counterclockwise along with the 1 circle will tune it to 50 ohms. The easiest way is add a capacitor in series with the antenna. (The capacitance can be calculated from the inductor value given by the network analyzer). Start with the capacitor value from the calculation, and check the impedance with the network analyzer. Adjust the value of the series capacitor untill the antenna impedance is tuned close enough to the center (50 ohms).

b. Tuning Antenna 2: It is located on the lower half on the 1 circle of the Smith chart as a capacitive load. The capacitance value can be read from the right top corner. Moving it to the center clockwise along the 1 circle will tune it to 50 ohms. The easiest way to do this is to add an inductor in series with the antenna. Adjust the value of the series inductor and check the overall impedance with a network analyzer until the antenna impedance is close to 50 ohms.

c. Tuning Antenna 3: It is located on the upper half of the 1 circle of the Admittance chart as an inductive load. Moving clockwise to 50 ohms by using a shunt capacitor will be the easiest way to tune it. Adjust the value of the shunt capacitor and check the impedance with the network analyzer until the antenna impedance is close to 50 ohms.

d. Tuning Antenna 4: It is located on the lower half of the 1 circle on the Admittance chart as a capacitive load. Adding a parallel inductor will move it counterclockwise to the center (50 ohms). Adjust the value of the parallel inductor and check the impedance with the network analyzer until the antenna impedance is close to 50 ohms.

With standard value of the chip capacitors and inductors, it is difficult to tune the antenna impedance to <u>exactly</u> 50 ohm. Normally a range from 30 ohms to 70 ohms will be acceptable.

The following is a discussion for tuning antennas that are not located on the 1 circle.

2) Whip Antenna Tuning Examples

Whip antenna is a very good candidate for the ASH transceiver applications. For the characteristic of the whip antenna, please see Page 4 of the ANTENNAS FOR LOW POWER APPLICATIONS paper at www.rfm.com. The impedance of a whip antenna is not only decided by its size, but also by the affects of metal objects near the antenna. For example, if you mount the antenna on a big PCB with a large ground plane, or to a large metal frame, the antenna inductance and impedance tends to be reduced. That may make the antenna present a capacitance load. On the other hand, if you mount the same whip antenna on to a very small PCB, the impedance will be higher and will be inductive. In such a case the antenna will be miss-matched to the ASH transceiver. It should be tuned to present a better match for good performance.

Example: Whip Antenna mounted on to a metal frame (capacitance load)
Mounting the whip antenna to a large metal frame will reduce the antenna inductance and impedance. Fig. 4 shows a whip antenna where the PCB is mounted on to a metal frame, and presents a capacitance load at "**X**". There are a number of ways to tune the antenna to 50 ohms. We will introduce the four easiest methods for the tuning. *On the Fig. 5, the Smith chart and the Admittance chart are put together for easy understanding.*

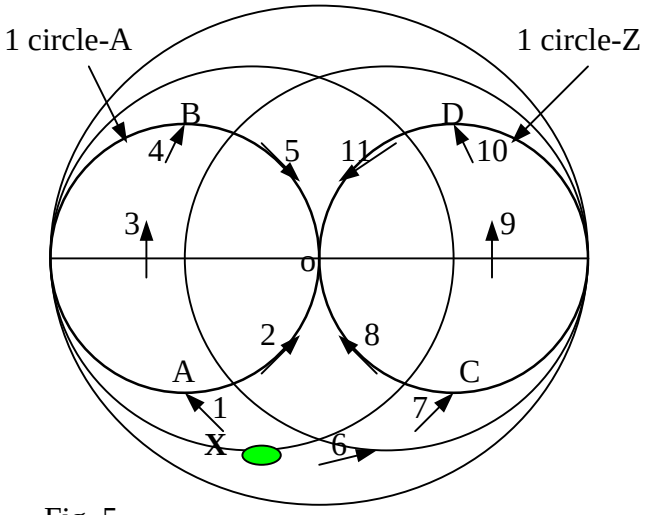
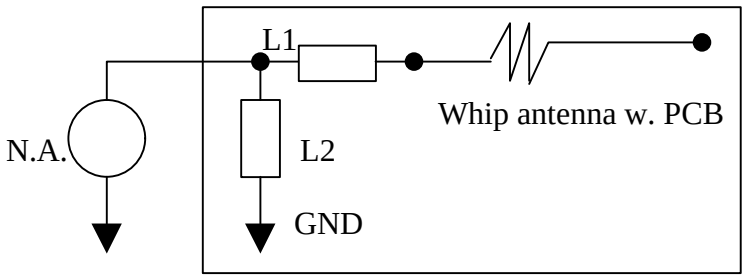


Fig. 5

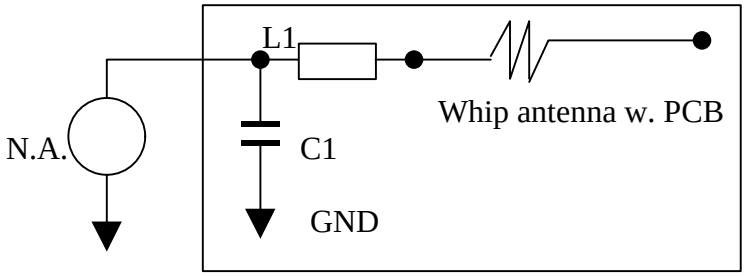
Method 1:
Step 1: Add a serial inductor, L1, to move the impedance from “X” to “A” along path 1 (“A” is just located on the 1 circle-A of the admittance chart).
Step 2: Add a shunt inductor, L2, to move from “A” to “O” along path 2.

Schematic:



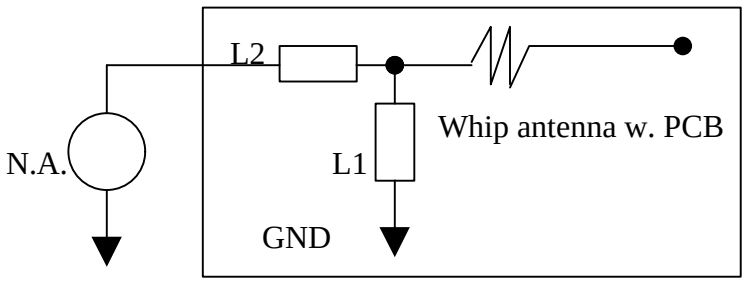
Method 2:
Step 1: Add a serial inductor, L1, to move the impedance from “X” passing through “A” to “B” along path 1 - 3 - 4. (“B” is just on the 1 circle-A of the admittance chart).
Step 2: Add a shunt capacitor, C1, to move from “B” to “O” along path 5.

Schematic:



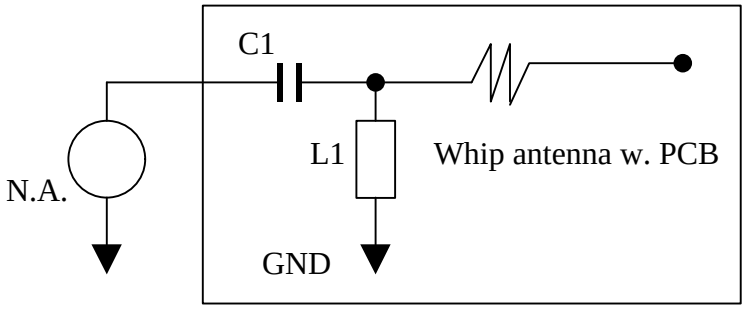
Method 3:
Step 1: Add a shunt inductor, L1, to move the impedance from “X” to “C” along path 6 - 7 (“C” is just on the 1 circle-Z of the Smith chart).
Step 2: Add a series inductor, L2, to move from “C” to “O” along path 8.

Schematic:



Method 4:
Step 1: Add a shunt inductor, L1, to move the impedance from "X" through "C" to "D" along the path 6 - 7 - 9 -10 ("D" is just on the 1 circle-Z of the Smith chart).
Step 2: Add a series capacitor C1, moves it from "D" to "O along with path 11.

Schematic:



3) Slot Antenna Tuning Examples
The slot antenna is another good antenna for high frequency ASH transceiver (868 MHz and 916 MHz). See page 12 of the ANTENNAS FOR LOW POWER APPLICATIONS. Normally, a slot antenna on a compact PCB will present an inductive load. On Fig. 6, "X" shows one example of the impedance of a slot antenna.

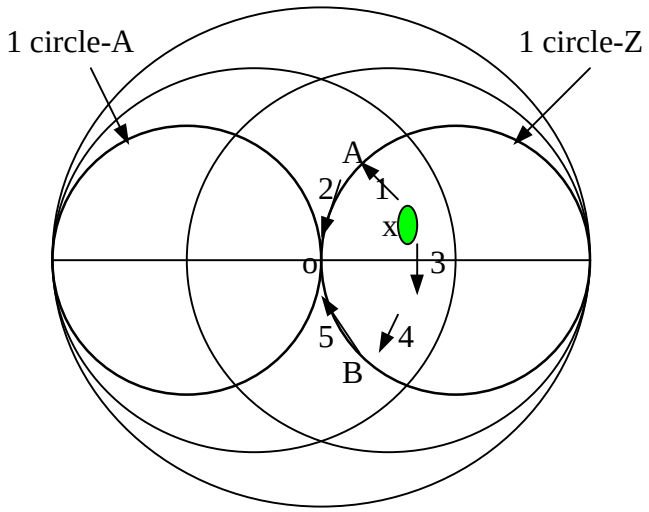
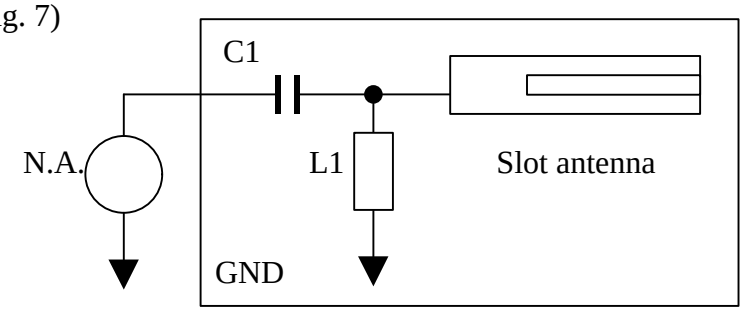


Fig. 6

There are again many methods to tune the antenna to 50 ohms. We will introduce the two easiest methods of tuning.

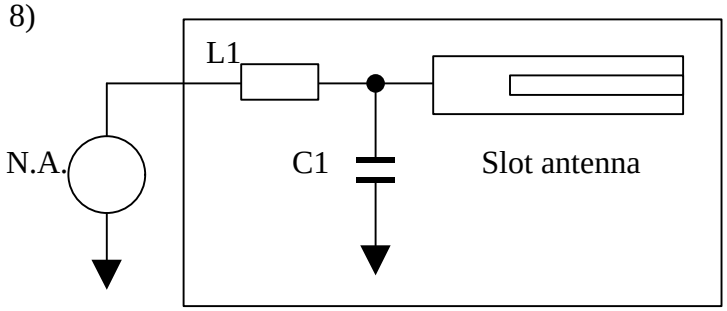
Method 1:
Step 1: Add a shunt inductor, L1, to move the impedance from "X" to "A" along path 1 ("A" is just on the 1 circle-Z of the Smith chart).
Step 2: Add a series capacitor, C1, to moves from "A" to "O" along path 2.

Schematic: (Fig. 7)



Method 2:
Step 1: Add a shunt capacitor, C1, to move the impedance from "X" to "B" along the path 3 - 4. ("B" is just on the 1 circle-A of the smith chart).
Step 2: Add a series inductor, L1, to move it from "B" to "O" along path 5.

Schematic: (Fig. 8)



3. **Connections with ASH Transceiver**
After the antenna is tuned to 50 ohms it can be connected to the ASH transceiver (with the two 50 ohm impedance matching inductors). Since there are several different matching circuits that can be used, the connection with the ASH transceiver will be different. We will discuss these connections separately.

1) Connection with Series Inductor
a). For the TR1000, TR1001, TR3002: L_{AT} matches the impedance of the TR to 50 ohms. The L_{ESD} is ESD chock has a high value, and will not affect the tuning. The direct connection between the antenna and the transceiver is showed below.

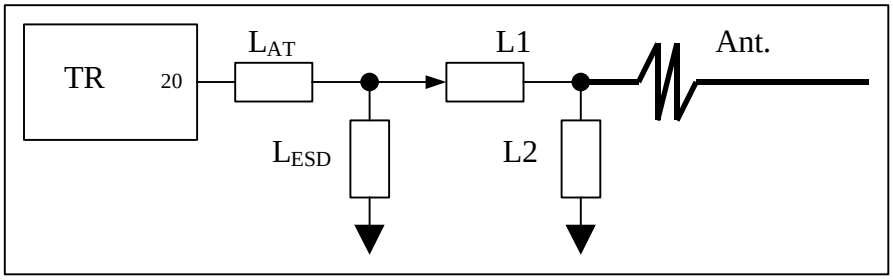


Fig. 9

This connection can be simplified. Since there is L2 connected to ground, the L_{ESD} can be deleted, and then the L_{AT} series with L1 can be replaced with one inductor. See Fig. 10.

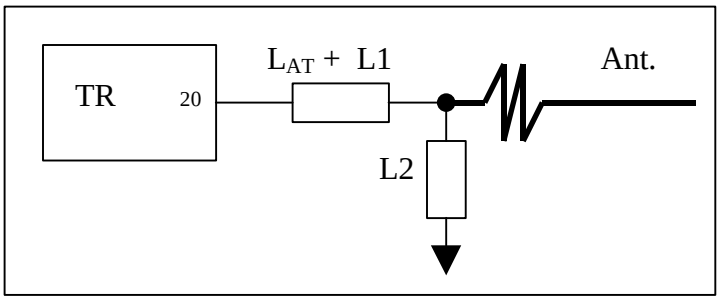


Fig. 10

b). For the TR3001 and TR3003: The L_{AT} and the L_{ESD} together matched the impedance of the TR to 50 ohms. The L_{ESD} is not only a ESD chock. In such case the connection with the antenna should follow the Fig. 9.

2) Connection with Shunt Inductor

The direct connection between the antenna and the transceiver is showed below.

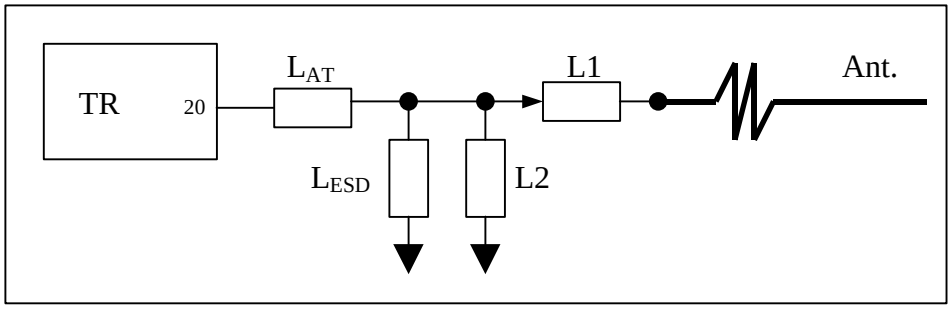


Fig. 11

Simplified circuit: Since there is L2 parallel with the L_{ESD}, the two inductors can be replaced with one inductor, and suitable for connect to all the ASH transceivers.

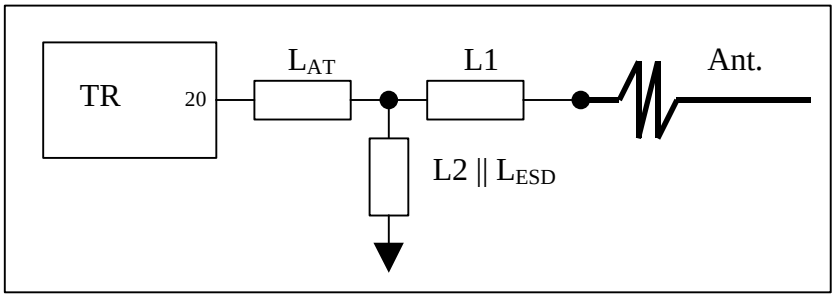


Fig. 12

3). Connection with Series Capacitor

The direct connection between the antenna matching circuit and the transceiver is showed below:

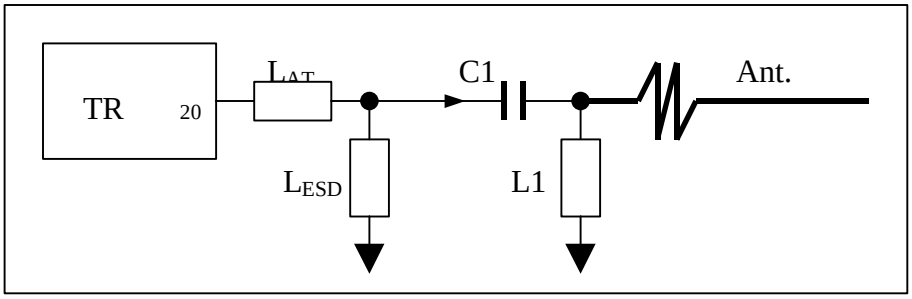


Fig. 13

4). Connection with Shunt Capacitor

The direct connection between the antenna matching circuit and the transceiver is showed below.

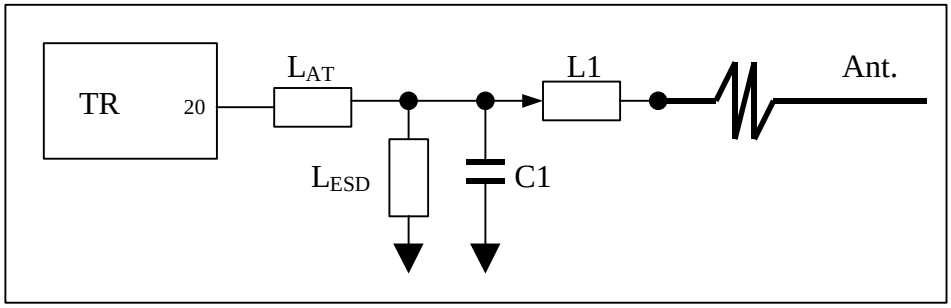


Fig. 14

Conclusion: In this application note we have introduced ASH transceiver antenna matching methods. There are many methods that can be used to match a given antenna to 50 ohms. The best way is with the fewest components that result in a good match. For this goal, it is best to plan it in advance. A Smith chart and Admittance chart worksheet is attached below with the following recommended procedure:

1. Calibrate the pigtail with network analyzer carefully.
2. Check the antenna impedance
3. Plan the matching path on the work sheet.
4. Drawing the matching circuit.
5. Start your tuning bench activities using a network analyzer
6. Combine the antenna matching circuit with the Ash transceiver 50 ohm matching circuit, and then try to simplify it.
7. Make range test.

By: Jie Nie, 11/02/2001 at RFM

Smith chart work sheet