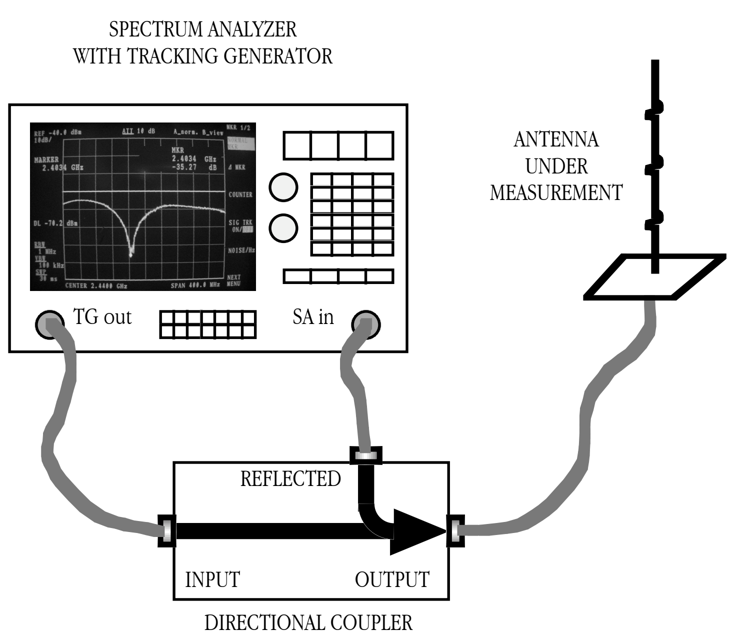
Antenna Measurements

The electrical characteristics of an antenna that are of interest to obtain by direct measurement are:

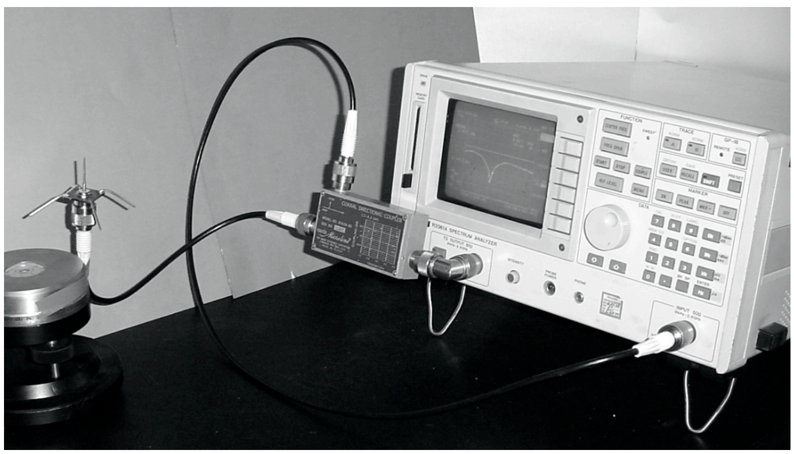
1) The frequency at which the antenna is tuned.
2) The gain.
3) The radiation pattern.

Tuning of an antenna.

To check if an antenna is tuned at the correct frequency, we can use a Directional Coupler and a Spectrum Analyzer. The signal is internally generated by the Tracking Generator of the Spectrum Analyzer, which is connected to the input port of the Directional Coupler. The antenna is connected to the output port of the Directional Coupler.

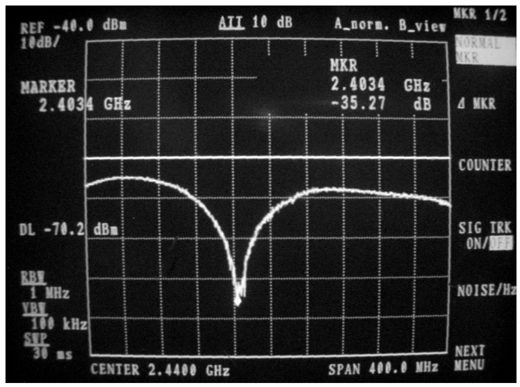


The signal reflected by the antenna is sampled at the reflected port of the Directional Coupler and displayed on the Spectrum Analyzer. We can then check if the minimum amount of reflected power corresponds to the correct frequency value, and if the amount of reflected power is low enough. Be careful to correctly terminate the other ports with 50 Ω dummy loads if the Directional Coupler is of the bidirectional type and to keep the cables as short as possible to avoid any resonance effect. The best electric length for cables is a N times the half wavelength.



To easily read the value of the reflected power, a calibration of the Spectrum Analyzer is required. In a first step, the reflected power when no antenna is connected to the output port of the Directional Coupler should be measured, and this value should be set as the reference value. In a second step, the power reflected by the antenna under test should be measured. In this way, we measure how much lower the reflected power is, in comparison to the case in which all the power is reflected.

For our quarter-wave omnidirectional antenna we got the following graph on the Spectrum Analyzer's screen:



We can see that the antenna is correctly tuned at 2.4 GHz, and the reflected power is about 35 dB less than the case without the antenna. This is a good result.

Measuring the gain.

To be consistent in comparing different antennas, it is necessary to have a standard environment surrounding the antenna. Ideally, measurements should be made with the measured antenna so far removed from any objects causing environmental effects that it can be considered in open space. This is an impractical situation. Professional laboratories use electromagnetic anechoic chambers (also called echo-free chambers) that simulate almost perfectly the open space situation. These are very expensive and for our purposes can be substituted by a roof, a terrace or an open field. The place should be as far as possible (at least 50 m) from power lines, aerials and microwave radio transmitters and without any metallic structure or conductive surface, concrete walls, other building, trees, etc. This is often difficult to achieve, but the environment should be controlled so that successful and accurate measurements can be made in a reasonable wide area.

To measure the gain of an antenna, three antennas are required:

a) The antenna under test
b) An antenna of known gain, that we will call Reference Gain
c) A third antenna which can be of unknown gain

Two measurements are required to determine the gain of the antenna under test. In each measurement, one antenna is connected to a transmitter, which can be a Signal Generator, and the other one is connected to a receiver, which can be a Spectrum Analyzer or a Power Meter. In our case, the receiver will be a Spectrum Analyzer. The antennas are mounted over tripods at fixed positions. The distance between the tripods should be more than a couple of meters to measure the far field. It is assumed that the three antennas have been carefully matched to the appropriate impedance and accurately calibrated and matched devices are being used. The antenna with known gain may be any type of antenna, which has been calibrated either by direct measurement or in special cases by accurate construction according to computed dimensions.

To prepare the measurement, switch on the Signal Generator and the Spectrum Analyzer well in advance and let them stabilize. Set the frequency of the Signal Generator to 2.44 GHz, with no modulation and disable the RF output until you connect the antenna. Set also the Spectrum Analyzer for a center frequency of 2.44 GHz and a frequency span of 20 MHz.

In the first measurement, the antenna of known gain is connected to the transmitter and the third antenna is connected to the receiver. Switch on the RF output of the Signal Generator and set its level high enough so that on the Spectrum Analyzer you can see the peak of the signal well over the noise floor. After arranging the two antennas to read the maximum value for the received signal, record this value on paper. This will be your Reference Level.

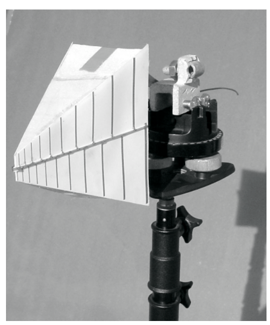
Without changing the position of the tripods nor the cables or connector/adapters, you should now exchange the antenna of known gain with the antenna under test. The value of the received signal must be read and recorded on paper as Measured Level.

The gain of the antenna under test is then given by:

Gain (dBi) = Reference Gain + (Measured Level - Reference Level)

The gains are expressed in dBi and the levels are expressed in dBm.

In our lab we have a 10 dBi calibrated directional antenna which we used as reference antenna.



As third antenna we used an omnidirectional antenna. According to the datasheet it has a 4 dBi gain, but as explained the knowledge of the gain of this antenna is not necessary. A photo of the omnidirectional antenna mounted on the tripod is shown.

Following the first measurement of the described procedure, we found a Reference Level of -64 dBm for the antenna of known gain.

We then exchanged the reference antenna with:

- the quarter wave omnidirectional antenna
- the collinear omnidirectional antenna
- the biquad antenna
- the cantenna



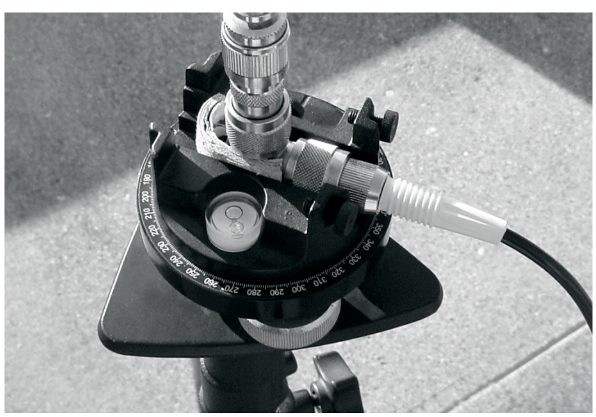

We obtained the results shown in this table.

	Measured Level (dBm)	Gain (dBi)
Reference Antenna	-64	10
Quarter Wave Omni	-70	4
Collinear Omni	-66	8
BiQuad	-62	12
Cantenna	-60	14

Measuring the antenna radiation pattern.

Of all antenna measurements considered, the radiation pattern is the most demanding in measurement steps and most difficult to interpret. Any antenna radiates to some degree in all directions into the space surrounding it. Therefore, the radiation pattern of an antenna is a three-dimensional representation of the magnitude, phase and polarization of the electromagnetic field. In most cases the radiation in one particular plane is of interest, usually the plane corresponding to that of the earth's surface, regardless of the polarization of the antenna. Measurements of radiation pattern should therefore be made in a plane nearly parallel to the earth's surface.

The technique to obtain radiation patterns is very similar in procedure to the one used to measure gain, but requires more equipment and time. For a relative antenna pattern measurement, just one antenna is needed in addition to the antenna under test and its gain does not necessarily need to be known. The antenna under test is connected to a transmitter, which can be a Signal Generator, and the other one is connected to a receiver, which can be a Spectrum Analyzer or a Power Meter. In our case, the receiver will be a Spectrum Analyzer. The antennas are mounted over tripods at fixed positions. For the antenna under test, a suitable mount is required which can be rotated in the horizontal plane with some degree of accuracy in terms of azimuth angle positioning. In the photo, one of such mounts is shown.



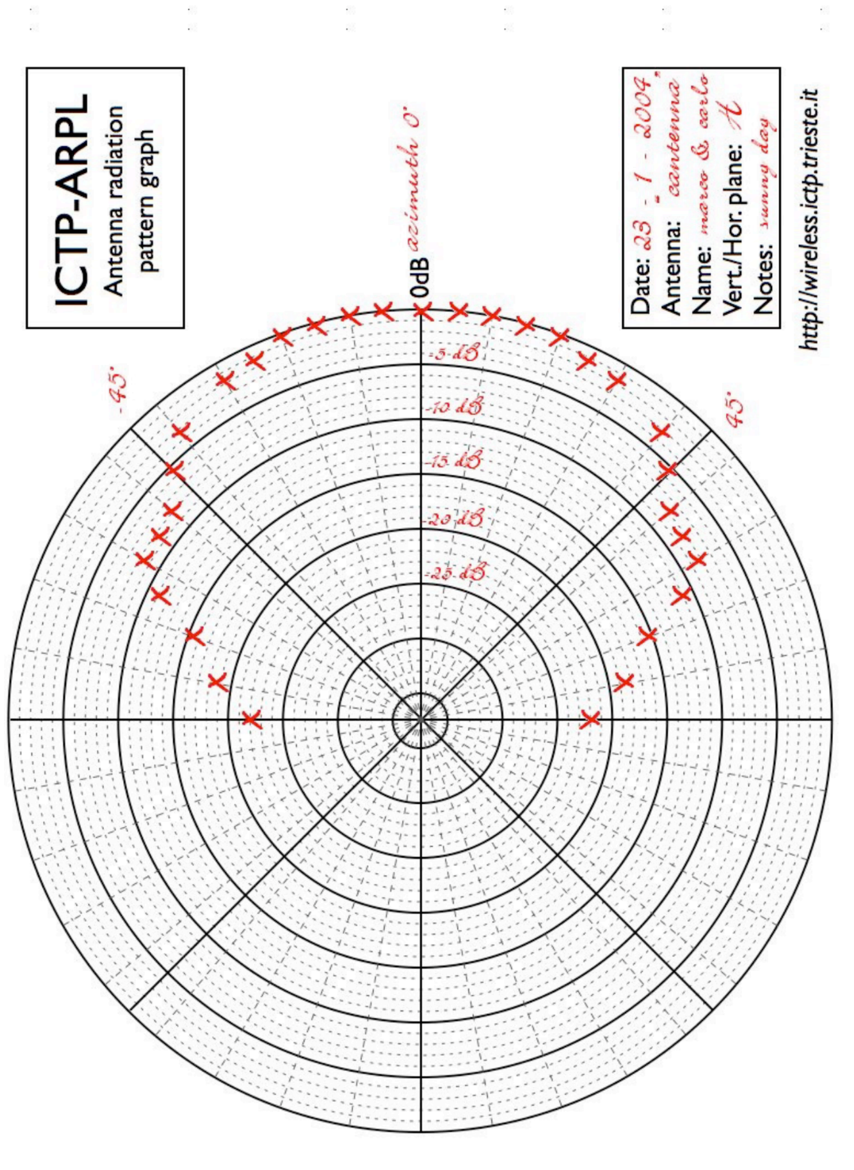
The distance between the tripods should be more than a couple of meters to measure the far field. It is assumed that the antennas have been carefully matched to the appropriate impedance and accurately calibrated and matched devices are being used.

To prepare the measurement, switch on the Signal Generator and the Spectrum Analyzer well in advance and let them stabilize. Set the frequency of the Signal Generator to 2.44 GHz, with no modulation and disable the RF output until you connect the antenna. Set then the Spectrum Analyzer for a center frequency of 2.44 GHz and a frequency span of 20 MHz. Align the geometrical axis of the antenna under test so that it points to the reference antenna. Set the zero of the azimuth scale. The elevation angle of the antenna under test should be also zero, and the two antennas should be at the same height. Connect the antennas, switch on the RF output of the Signal Generator and set its level high enough so that on the Spectrum Analyzer you can see the peak of the signal well over the noise floor. Record the value you read on the Spectrum Analyzer's screen on paper. This will be your Reference Level.

Without changing the elevation setting, carefully rotate the antenna in azimuth in small steps of 5 degrees. You can alternatively rotate the antenna to permit signal-level readout of 3 dB per step. These points of signal level corresponding with an azimuth angle are recorded and then plotted either manually on polar coordinate paper or printed with the use of a computer. On the polar paper, the measured points are marked with an X and a continuous line is then drawn by hand, since the pattern is a continuous curve.

Following the described procedure, we measured the radiation pattern of the cantenna. We aligned the cantenna with the receiving one, that in our case was a 4 dBi omnidirectional one. We reset the azimuth angle to zero. The value read on the Spectrum Analyzer, which was used as Reference Level, was -60 dBm. In the following pages, there is a table with the values read rotating the antenna of 5 degrees at a time in both directions and the hand-made graph of the radiation pattern. From the radiation pattern graph, the 3 dB beamwidth can be estimated in the order of 70 degrees. Due to obstacles near the area of measurement, the angle range was limited to 180 degrees.

Angle (degrees)	Measured Level (dBm)	Rel. Gain (dB)
0	-60	0
5	-60	0
10	-60	0
15	-60.25	0.25
20	-60.25	0.25
25	-61.37	1.37
30	-61.87	1.87
35	-63.25	3.25
40	-64.75	4.75
45	-65.5	5.5
50	-67.75	7.75
55	-68.37	8.37
60	-68.37	8.37
65	-71.35	11.35
70	-75.62	15.62
80	-78.75	18.75
90	-82	22
-5	-60	0
-10	-60	0
-15	-60.45	0.45
-20	-60.45	0.45
-25	-61.58	1.58
-30	-61.95	1.95
-35	-63.63	3.63
-40	-65	5
-45	-65.8	5.8
-50	-68	8
-55	-68.7	8.7
-60	-68.75	8.75
-65	-71.5	11.5
-70	-76	16
-80	-78.9	18.9
-90	-82	22


ICTP-ARPL
Antenna radiation pattern graph
0dB
azimuth 0°
-3 dB
-10 dB
-15 dB
-20 dB
-25 dB
-45°
45°
Date: 23 - 1 - 2004,
Antenna: cantenna
Name: marco & carlo
Vert./Hor. plane: H
Notes: sunny day
http://wireless.ictp.trieste.it