Antenna Principles and Practical Design

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Ver.1.0

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- 4 The related parameters

Overview

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Overview

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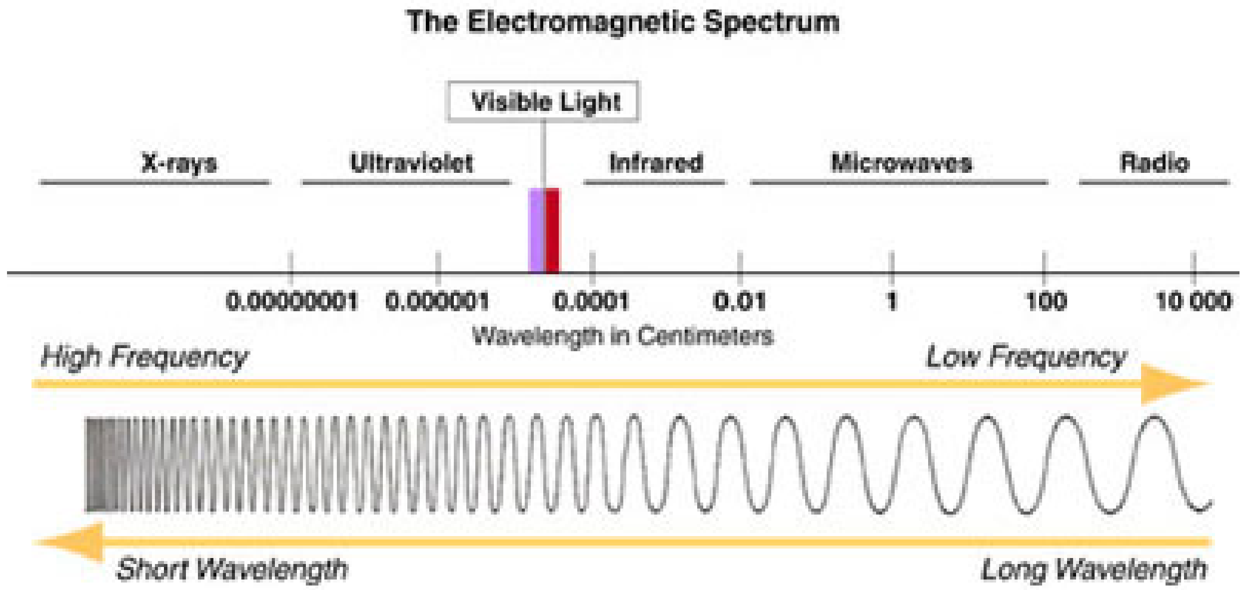
Part I: Antenna Principles

1 What's electromagnetic wave?



- Often referred to as radio waves, electromagnetic waves are waves of energy that are similar to light waves. They travel at the speed of light.

Definition:

- A radio wave can be visualized as a sine wave.

- The distance a wave travels to complete one cycle is known as the wavelength of the signal.

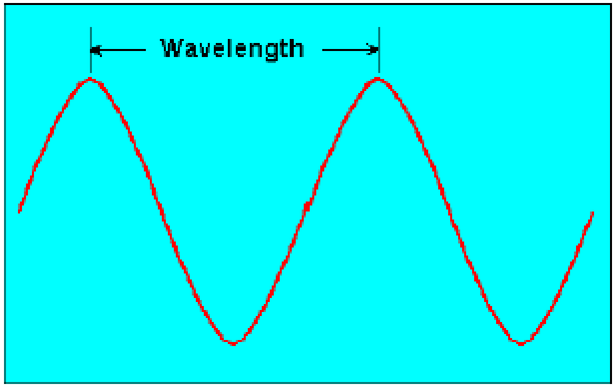
  A GSM signal (900 MHz) : 33 cm as it travels through the air.

  Visible light : less than 5 µm.

- $\lambda = c / f$

  λ: wavelength, c: the speed,

  f: the frequency (cycles per second).

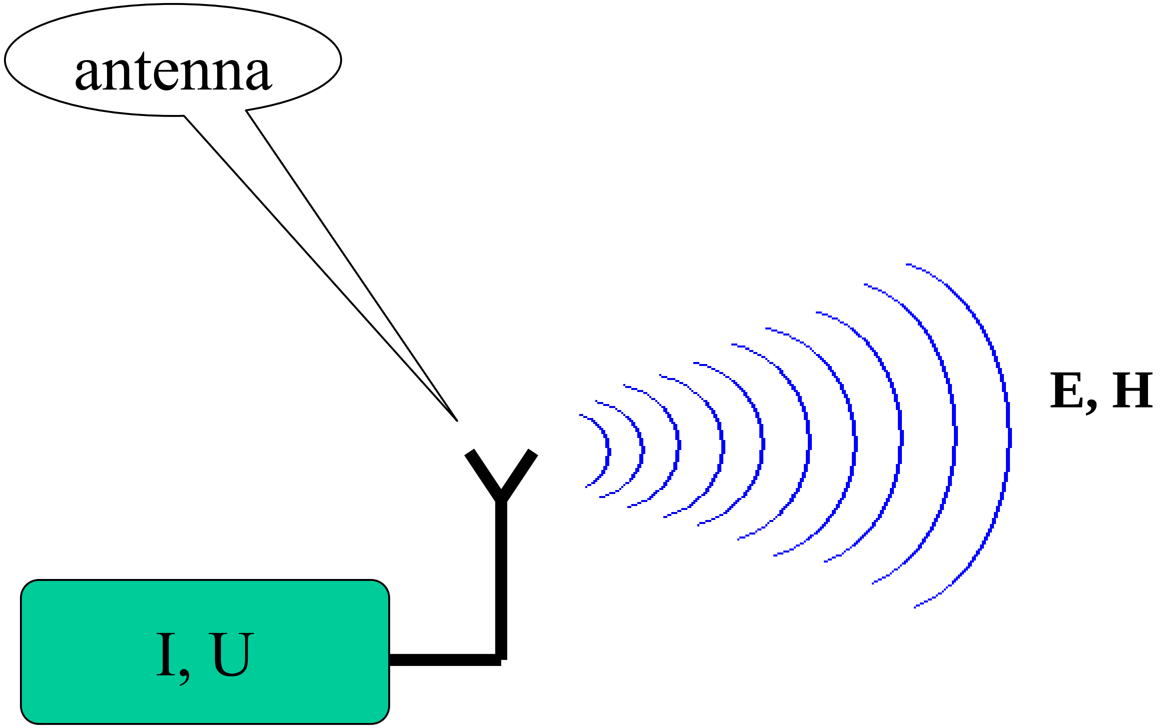


2 What's an antenna?

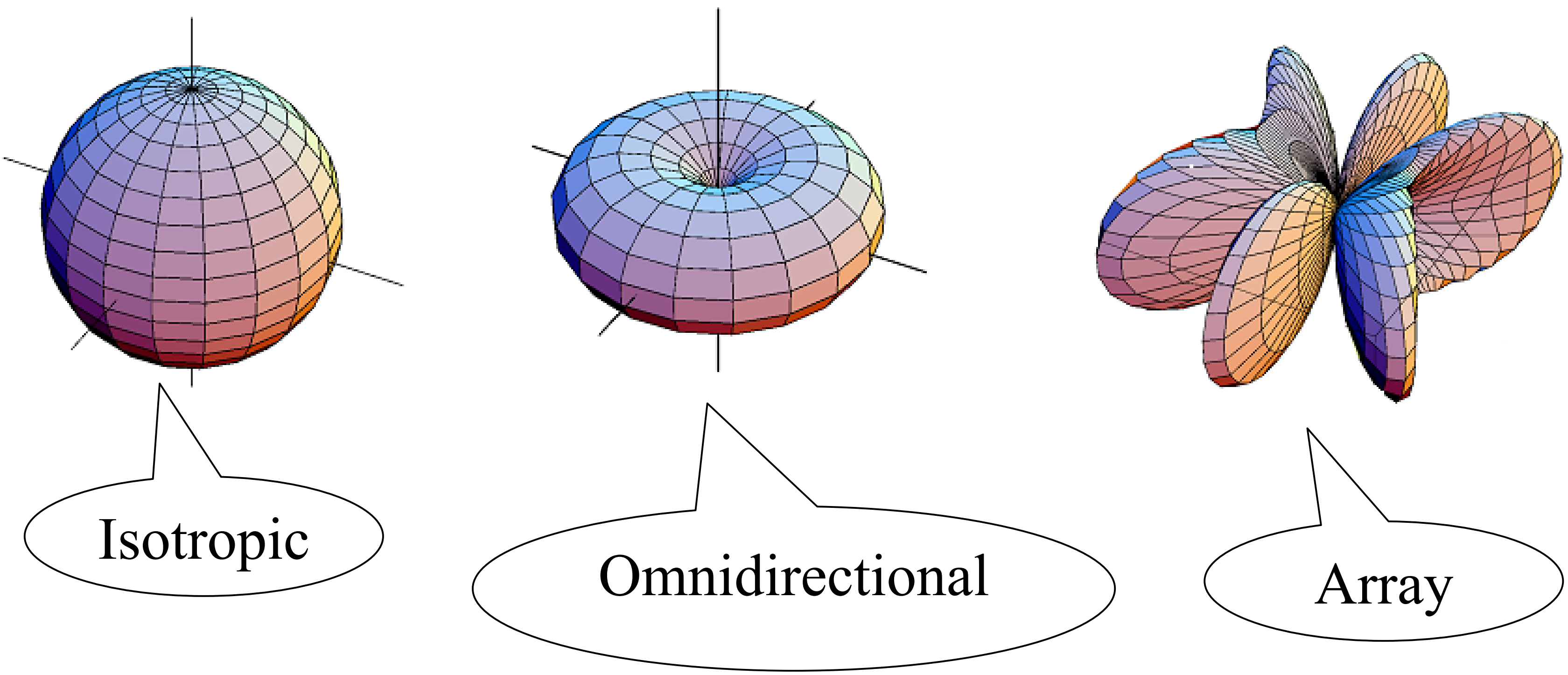
Definition:

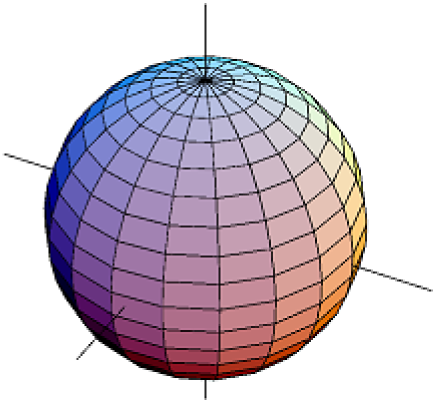
•The part of a transmitting or receiving system which is designed to radiate or to receive electromagnetic waves.

•The structure associated with the region of transition between a guided wave and a free-space wave, or vice versa


antenna
E, H
I, U

3 How does an antenna work?--Radiation





Isotropic Antenna

A hypothetical antenna that radiates or receives equally in all directions.

Isotropic antennas do not exist physically but represent convenient reference antennas for expressing directional properties of physical antennas.

4 The Related Parameters

The parameters we provide for the Customers:

Return Loss
VSWR
Gain

Antenna Design Criteria

Firstly: Return Loss and VSWR are as low as possible.
Gain is as high as possible.
Wider bandwidth

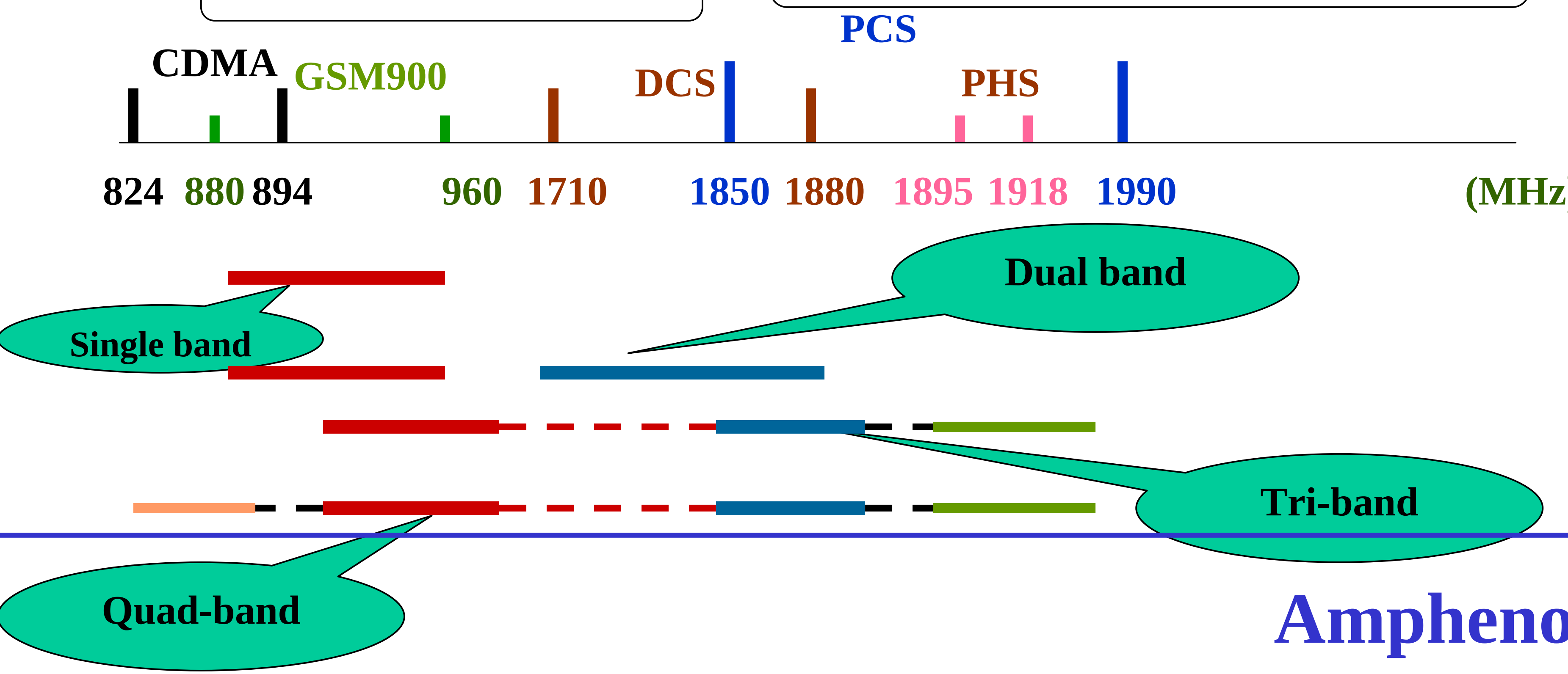
Secondly: To meet the requirements of the customers.
(maybe conflict with the first step.)

4.1 Frequency

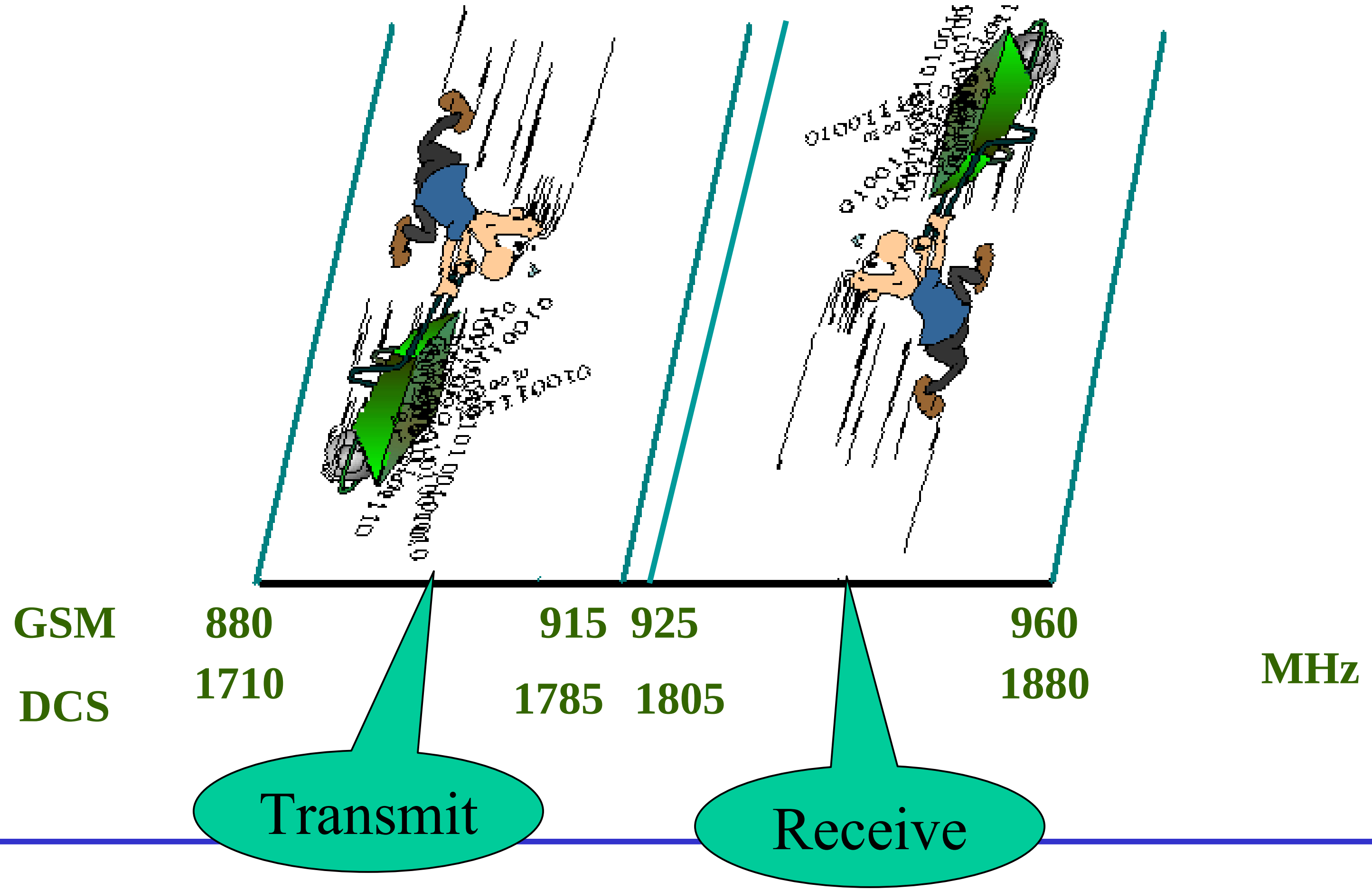
Frequency resource is the public property of the world.

2.5G: GPRS

WCDMA: 1920～1980MHz; 2110～2170MHz
3G: TD-SCDMA:1900～1920MHz; 2010～2025MHz
CDMA2000(1X):825 ～835MHz; 870 ～880MHz

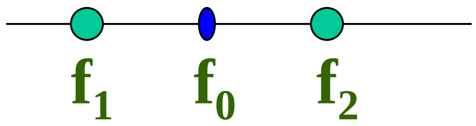


4.1 Frequency(2)



Definition: For a periodic function, the number of cycles or events per unit time.

4. 2 Bandwidth



Absolute Bandwidth = $f_2 - f_1$

(Relative) Bandwidth = $(f_2 - f_1) / f_0$

4.3 Antenna Matching

The process of adjusting impedance so that the input impedance of an antenna equals or approximates the characteristic impedance of its transmission line over a specified range of frequencies.

Note: The impedance of either the transmission line, or the antenna, or both, may be adjusted to effect the match.

Measurement: Network Analyzer

4.4 Return Loss

Return Loss = 10lg $\frac{\text{Reflected Power}}{\text{Input Power}}$

The ratio, at the junction of a transmission line and a terminating impedance or other discontinuity, of the amplitude of the reflected wave to the amplitude of the incident wave.

Return Loss = 20lg|Reflection coefficient|)

$-\infty$ < **Return Loss** <=0

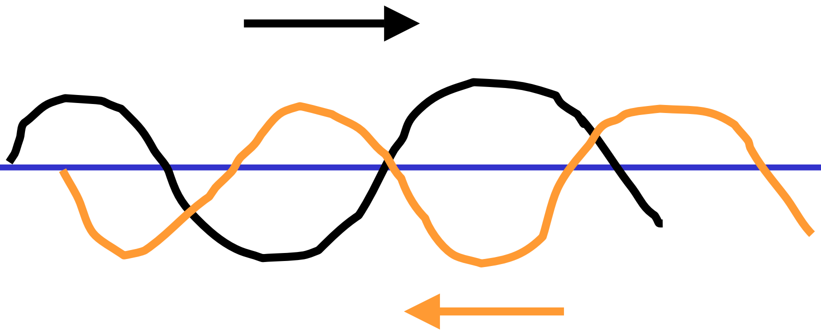
|**Reflection Coefficient**|<=1

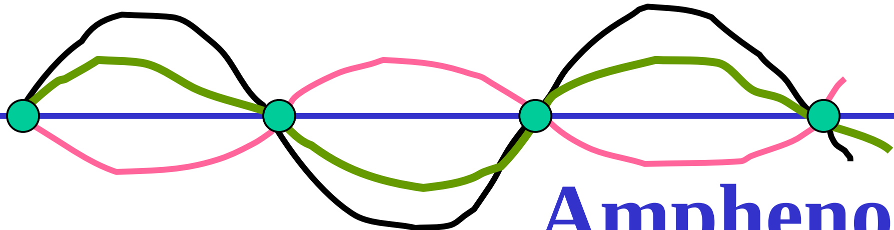
Return Loss is usually expressed in dB.

4.5 Standing Wave

In a transmission line, a wave in which the distribution of current, voltage, or field strength is formed by the superposition of two waves propagating in opposite directions, and which wave is characterized by a series of nodes (maxima) and anti-nodes (minima) at fixed points along the transmission line

A standing wave may be formed when a wave is transmitted into one end of a transmission line and is reflected from the other end by an impedance mismatch, *i.e.* , discontinuity, such as an open or a short.





Amphenol

4.6 VSWR
(Voltage Standing Wave Ratio)

$$VSWR = \frac{\text{Maximum Voltage of Standing Wave}}{\text{Minimum Voltage of Standing Wave}}$$

It varies from 1 to + ∞ .

4.6 VSWR(2)
(voltage Standing Wave Ratio)

It varies from 1 to + ∞.

VSWR = 1:1 = >100% transmitted

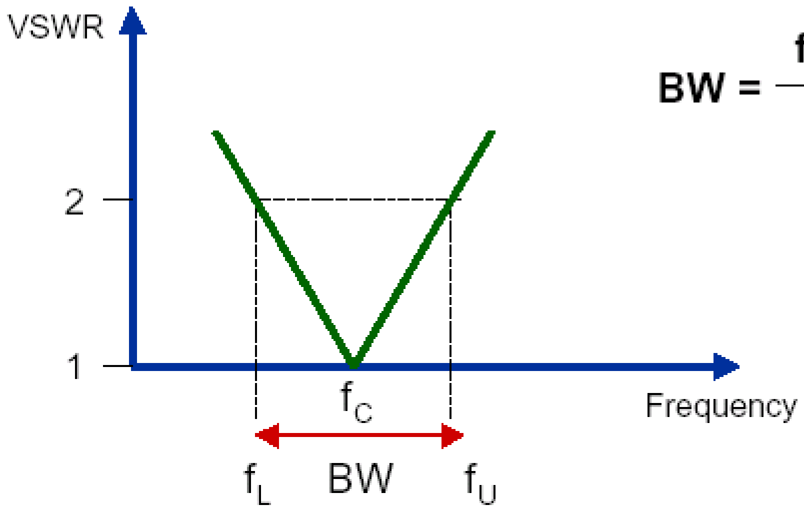
VSWR = 2:1 => 89% transmitted

The VSWR is a measure of impedance mismatch between the transmission line and its load.

The higher the VSWR, the greater the mismatch.

The minimum VSWR, *i.e.*, that which corresponds to a perfect impedance match, is unity.

4.7 VSWR and BW(bandwidth)

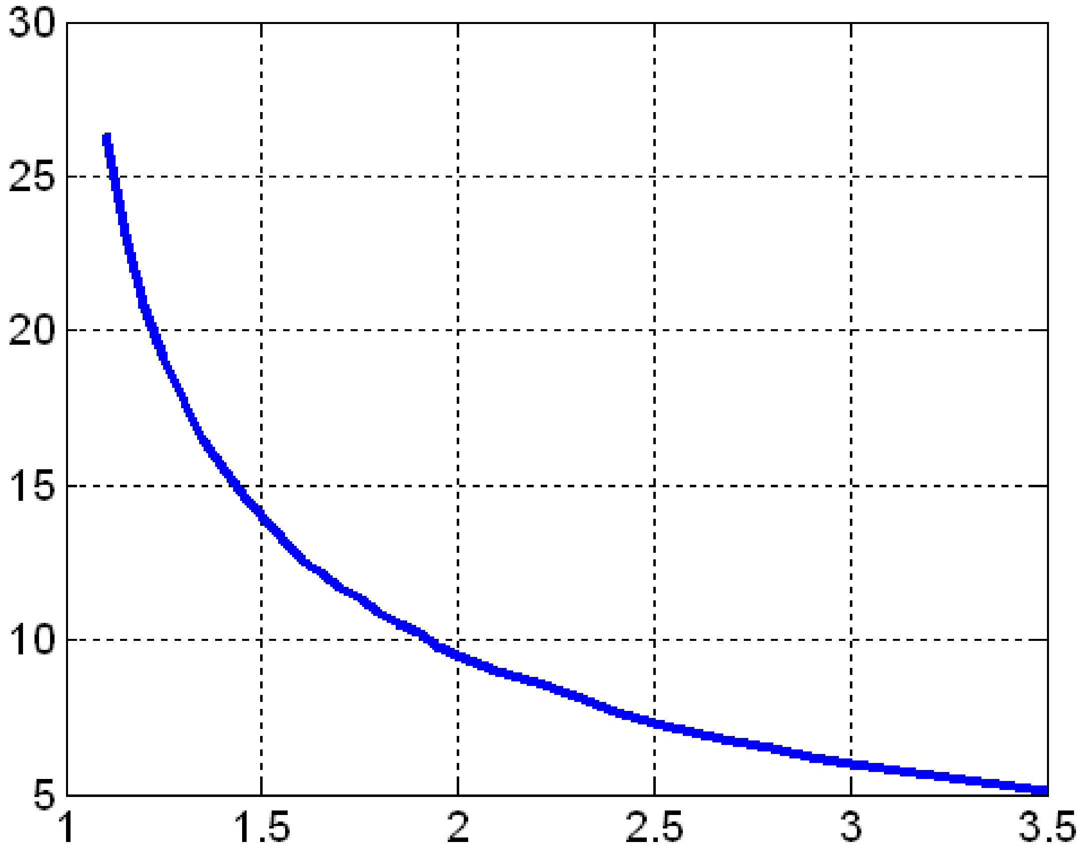


$$BW = \frac{f_U - f_L}{f_C} \times 100\%$$

f_C= Center frequency
f_L= Lower frequency
f_U= Upper frequency

4.8 VSWR and Return Loss

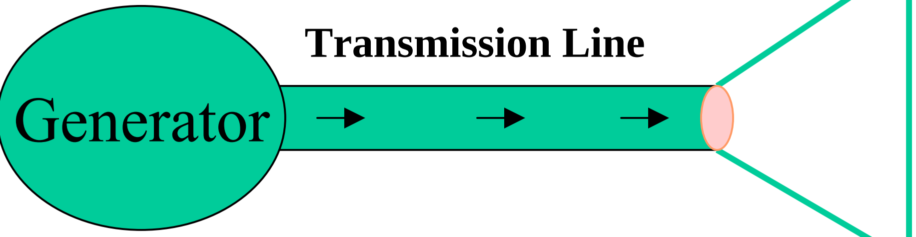
Return Loss



VSWR

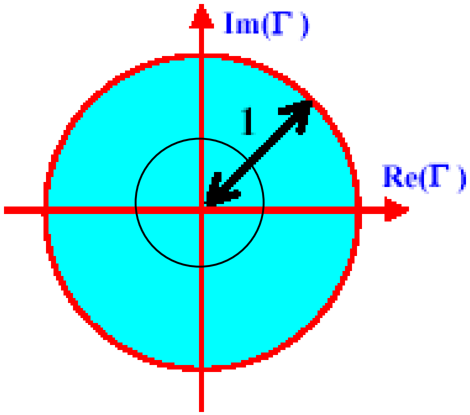
4.9 Input Impedance

Input Impedance = V_{in} / I_{in} (at feed point)



= Input resistance + j*(input reactance)
This is a complex number.

4.10 Smith Chart



The Smith chart is simply a representation of all possible complex impedances with respect to coordinates defined by the reflection coefficient.

The diameter of the circle with the centre (0,0) represent the absolute reflection coefficient.

0=<The diameter of the circle with the centre (0,0)<=1

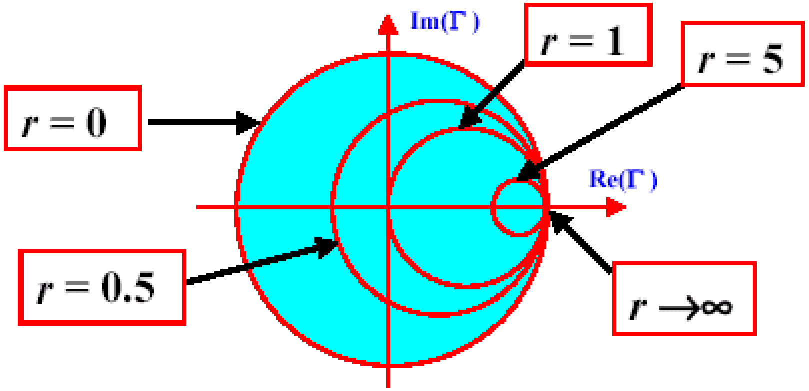
absolute reflection coefficient

4.10 Smith Chart(2)

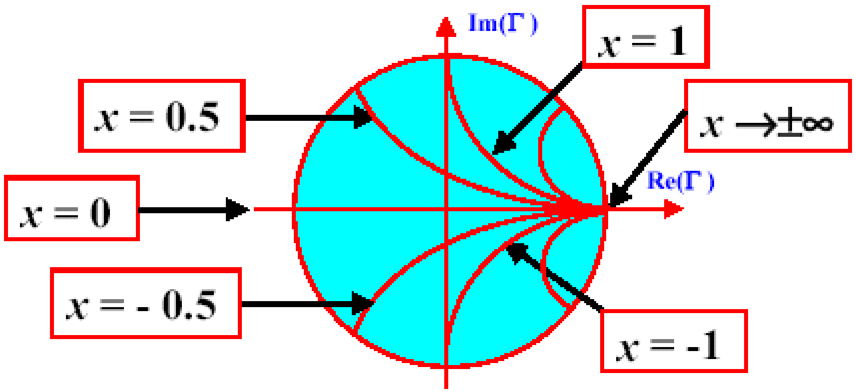
The Normalized Impedance z = Input Impedance/characteristic impedance Z_0

$$=\mathrm{Re}(z) + j\,\mathrm{Im}(z) = r + j\,x$$

常数电抗（正）圆

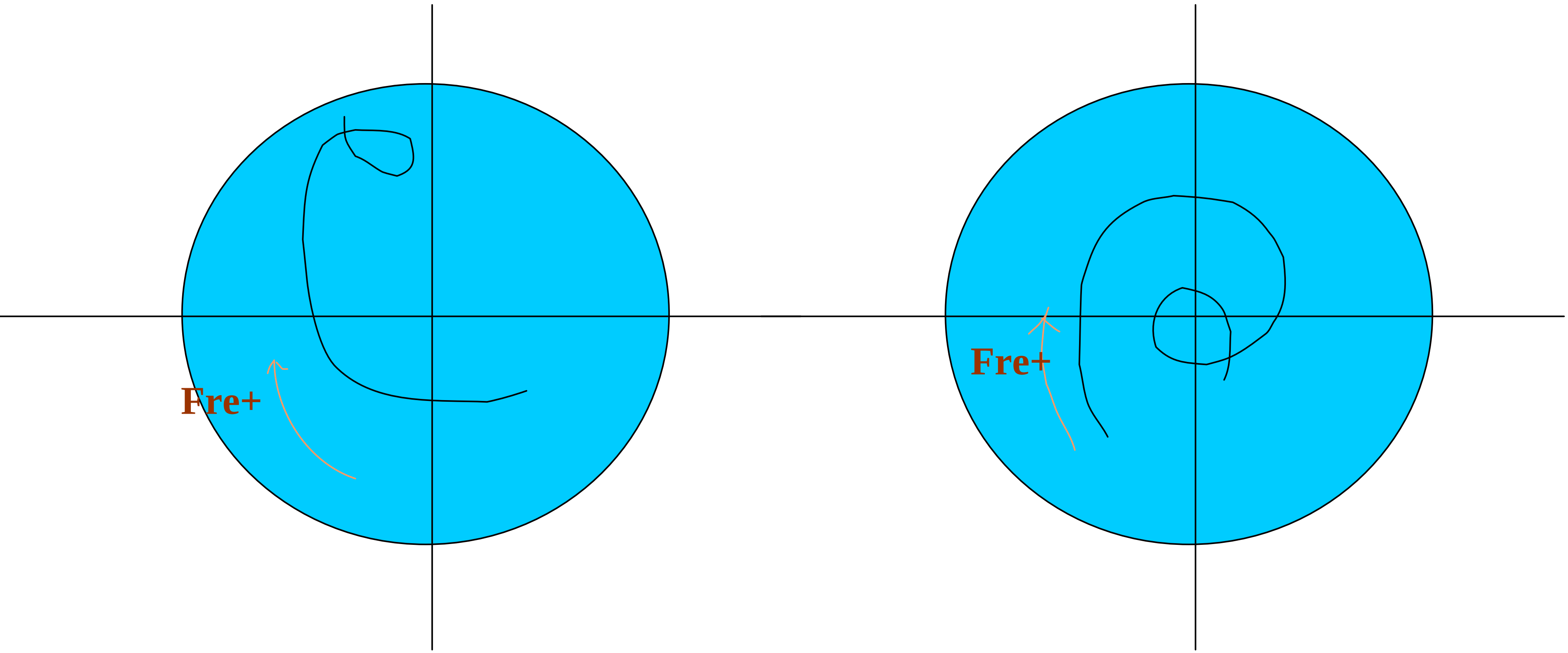


常数电阻圆

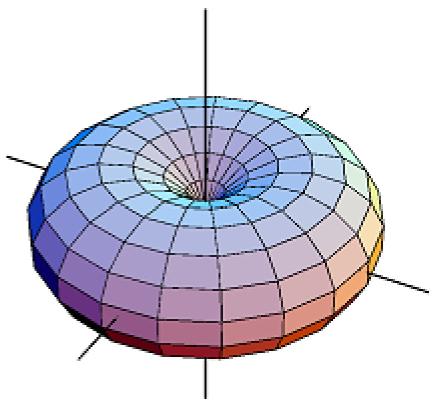


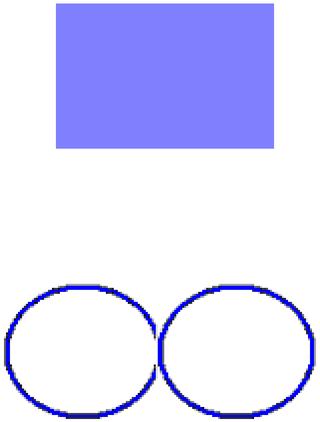
常数电抗（负）圆

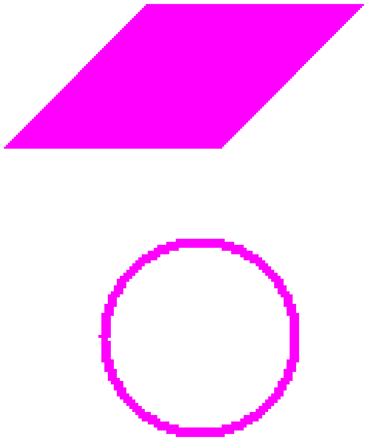
4.10 Smith Chart(3)



4.11 Radiation Pattern







Measurement:
Anechoic Chamber
(2D or 3D)

E plane
(// **E**)

H Plane
(//**H**)

Definition: The variation of the field intensity of an antenna as an angular function with respect to the axis.

4.12 Gain

Gain = Efficiency * Directivity

The ratio of the power required at the input of a loss-free reference antenna to the power supplied to the input of the given antenna to produce, in a given direction, the same field strength at the same distance.

增益是综合衡量天线能量转换和方向特性的参数。

物理意义

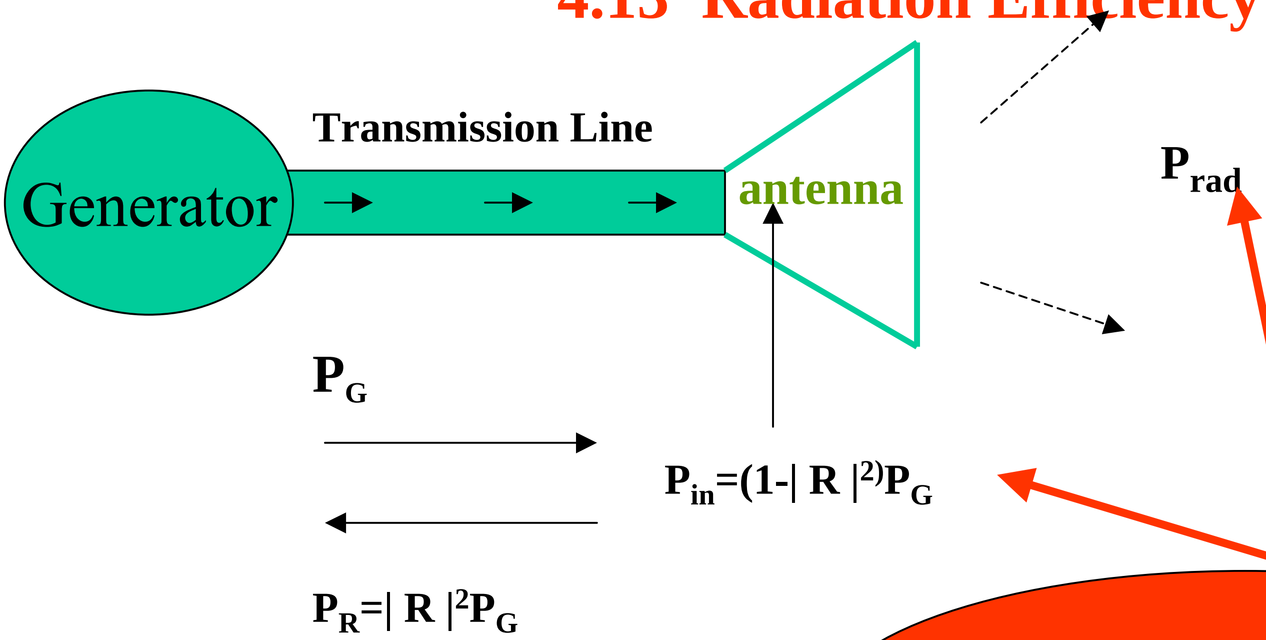
描述了天线与理想无方向性天线相比在最大辐射方向上将输入功率放大的倍数。

Measurement:
Anechoic Chamber
(2D or 3D)

Gain(dB)=10lg Gain(/max(Gain))

Gain(dBi)=10lg (Gain/Lossless Isotropic)=10lg(Gain)

4.13 Radiation Efficiency



Requirement
(Internal antenna)
>=30%

$$\text{Efficiency} = \frac{P_{rad}}{P_{in}}$$

P_G : The output power from the generator

P_R : The reflected power caused by the mismatch between antenna and transmission line.

R : The reflection coefficient

P_{in} : The power input the antenna

P_{rad}: the radiated power

Definition:
At a given frequency, the ratio of The power radiated to the total power supplied to the radiator.

4.14 Directivity

$$\text{Directivity} = \frac{\text{Maximum Radiation Intensity}}{\text{Average Radiation Intensity}}$$

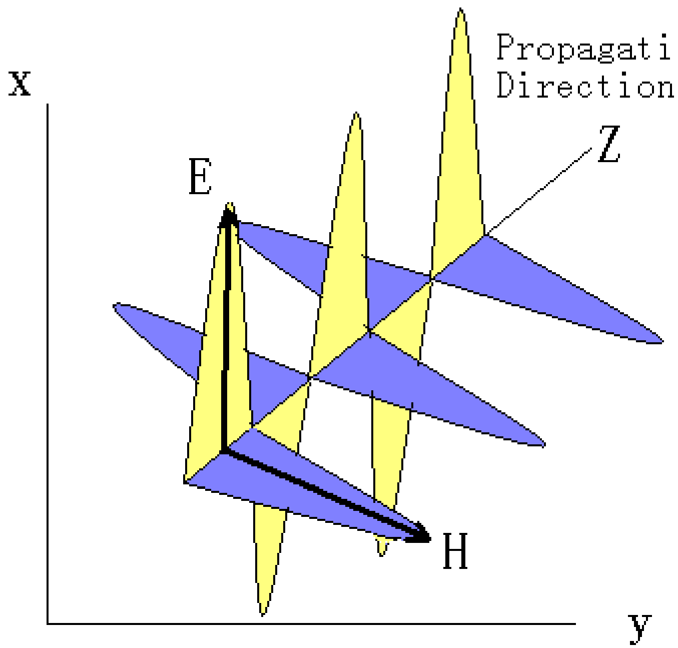
Example 1: Isotropic: Directivity=1

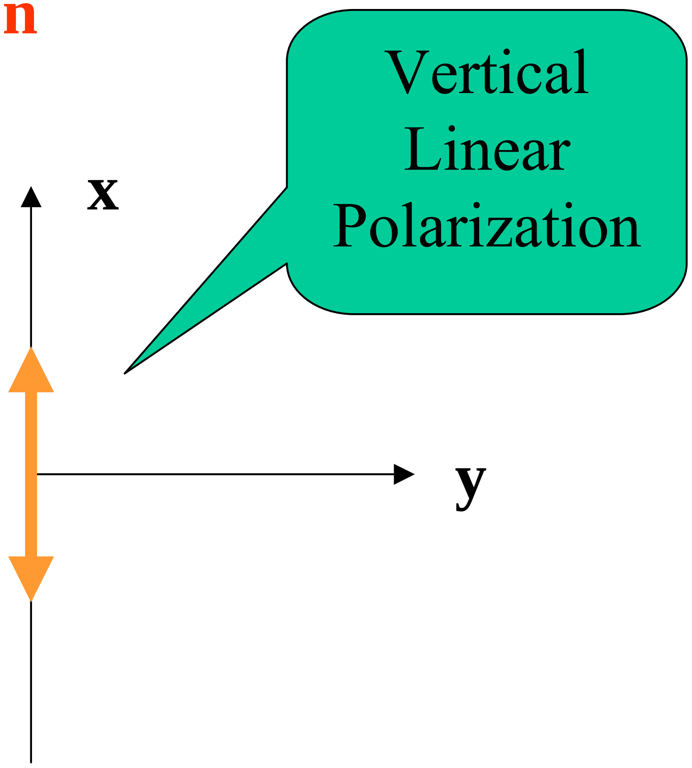
This is the smallest directivity an antenna can have.

Example 2: D=103=20dBi (dB above isotropic)

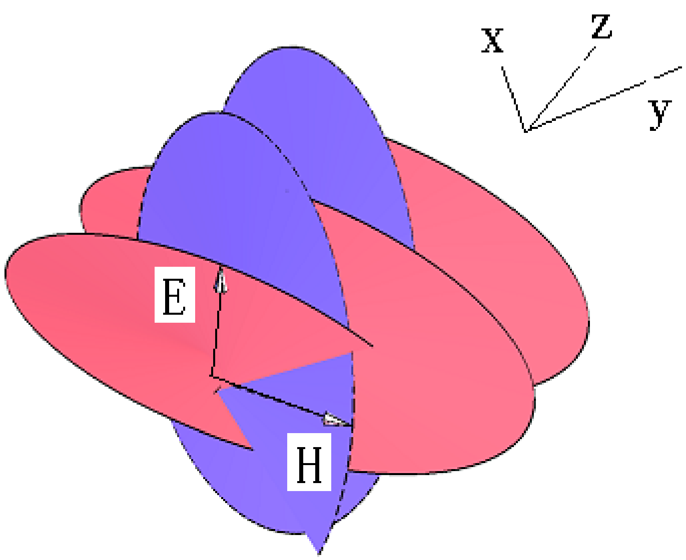
The antenna radiates a power in the direction of the main-lobe maximum which is about 100times as much as would be radiated by a nondirectional (isotropic) antenna for the same power input.

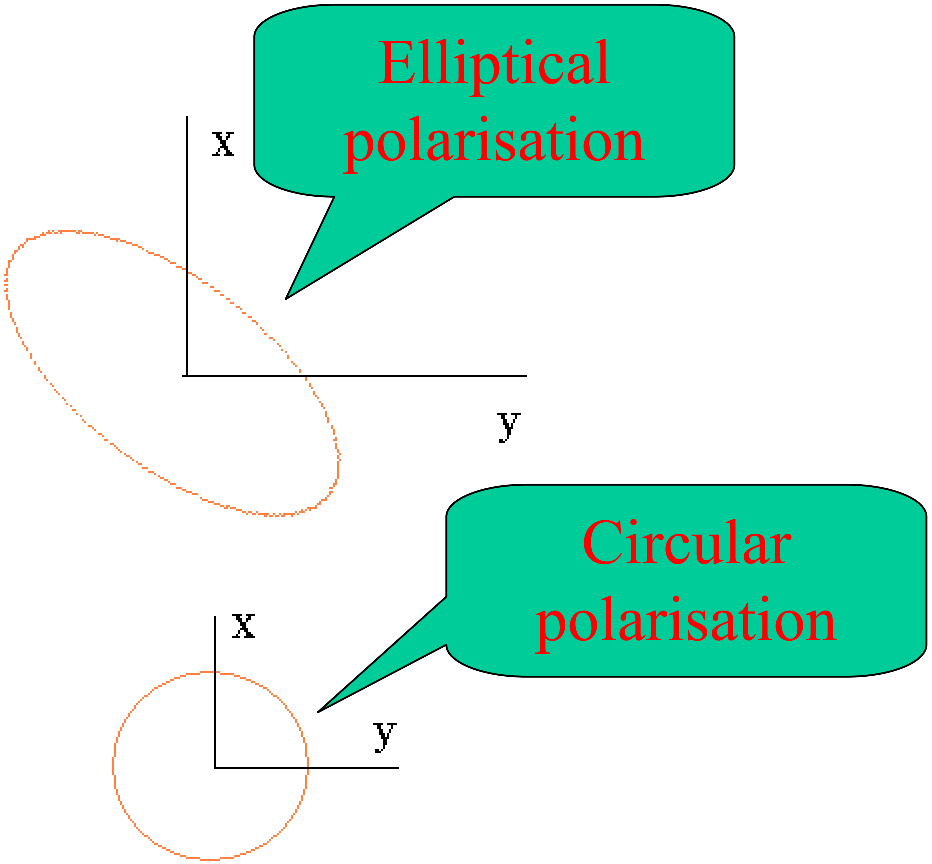
4.15 Polarization





4.16 Polarization (2)





4.17 SAR(Specific Absorption Rate)

The SAR is an indication of the amount of radiation that is absorbed into the body (usually the head) when using a cell phone.

- **the higher the SAR rating the more radiation that is emitted by the cell phone in a manner that can be absorbed by the head.**

Measurement:
DASY4

Part II: Practical Design

II.1 Stubby Antenna

Stubbies
(Fixed antennas)

Retractable
Antennas

1 Examples of the handset antennas

2 How to design antenna in RF perspective?

- **Network Analyzer**
  - Input impedance
  - S-parameters
  - Transmission measurements
- **Antenna Range**
  - Radiation pattern
  - Gain
  - Polarization
- **Simulation Tools**
  - IE3D
  - HFSS

2.1 RF Design Procedure of Stubby Antenna

* PL provides the information of RF requirements, frequency band and matching network.
* ME must discuss the coil dimension with RF engineer after ME gets the first mechanical drawing from the customers

Design the coil of first version based the coil size provided by ME

Get a handset with the main components

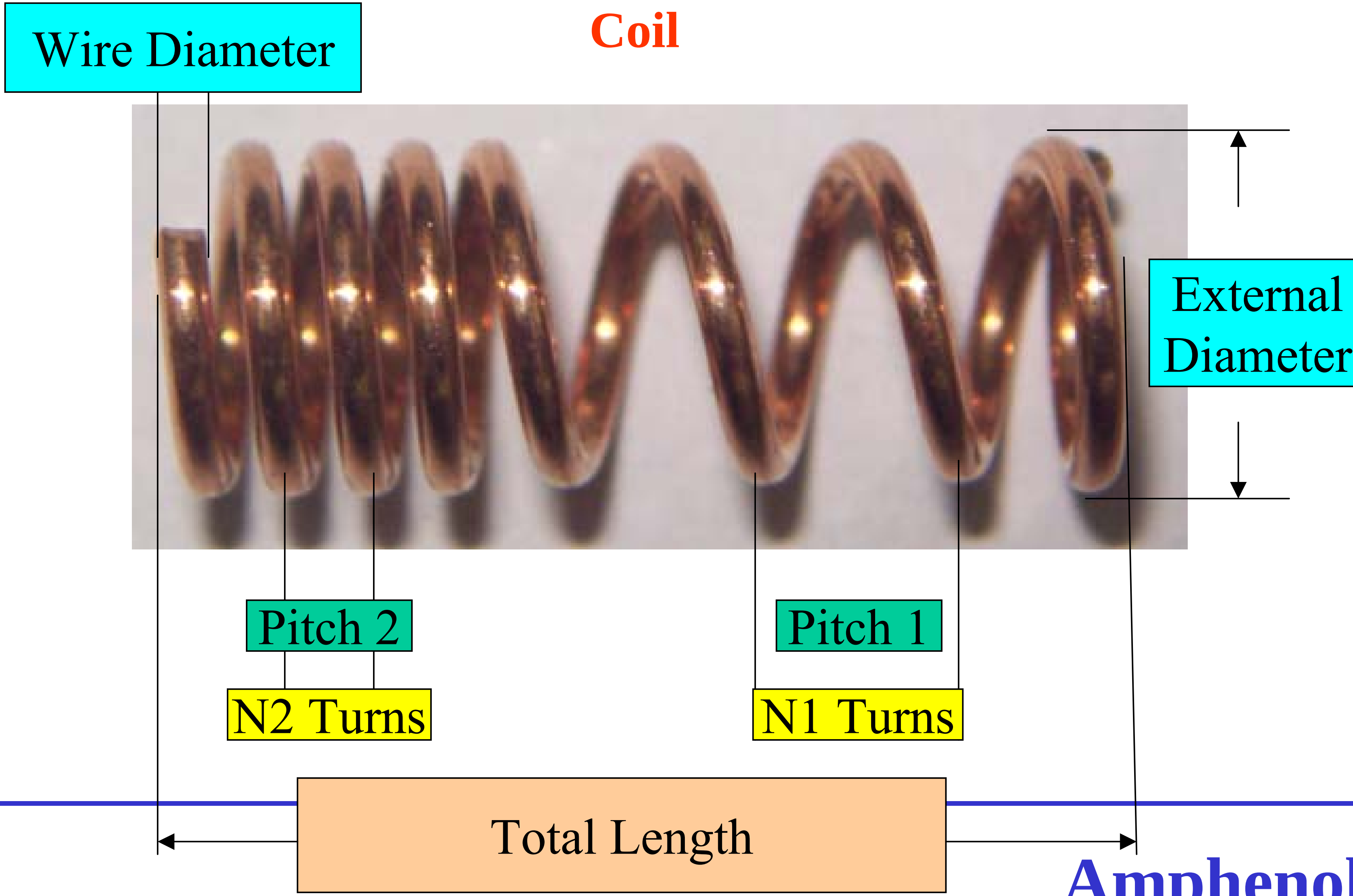
First Design: Lower VSWR and Return Loss, higher Gain

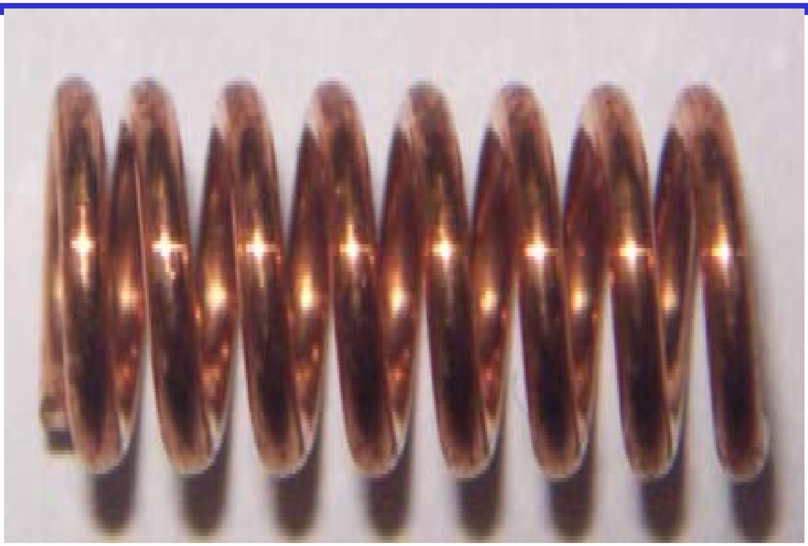
Following Design: handset change, feedback from the customers

2.3 Antenna Structure

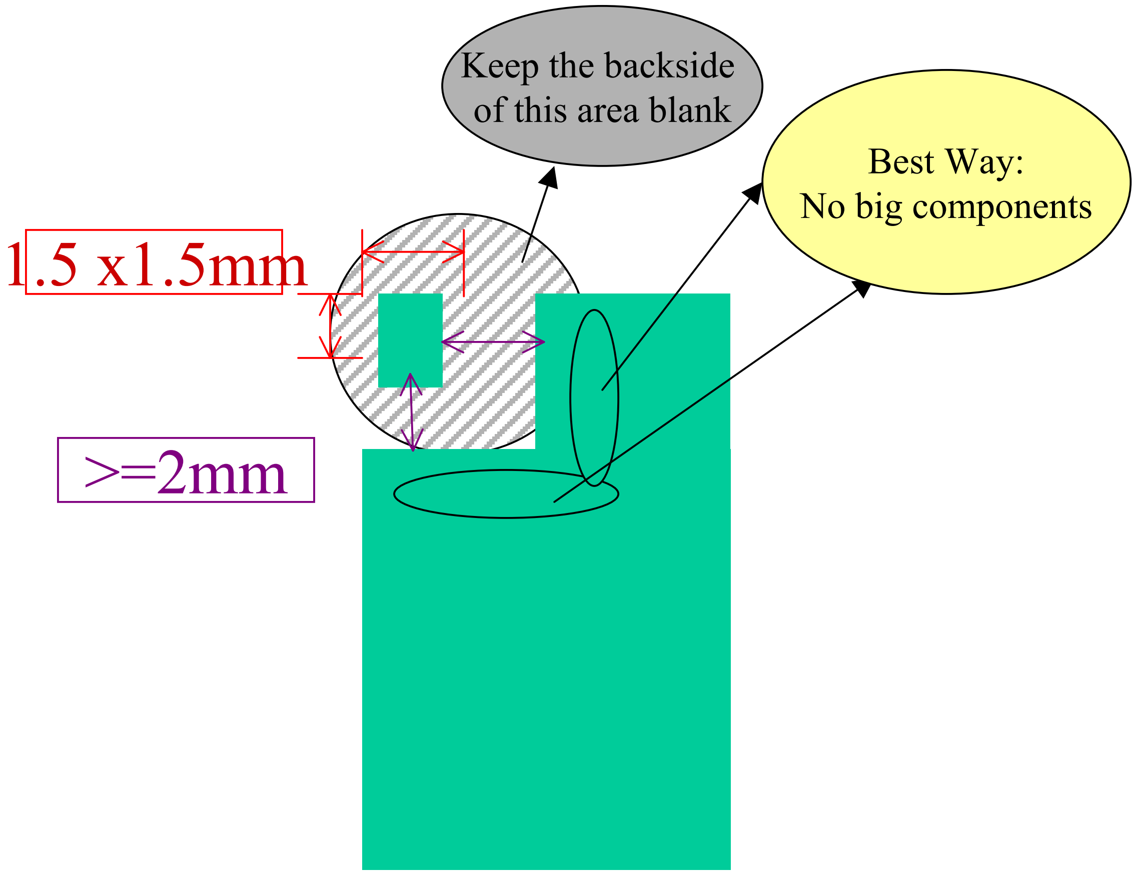
Retractable Antenna

Coil

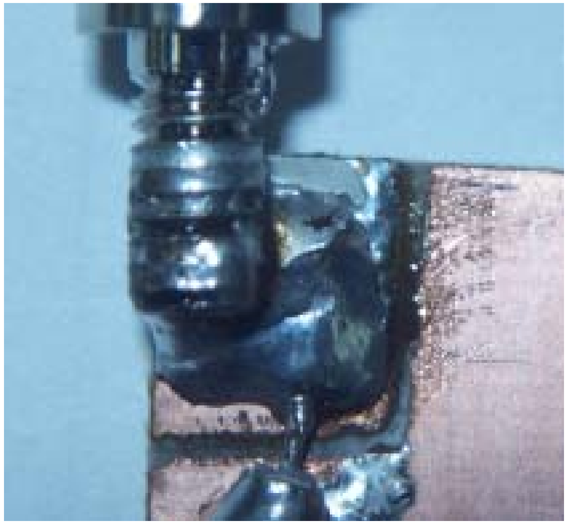

Wire Diameter
External Diameter
Pitch 2
Pitch 1
N2 Turns
N1 Turns
Total Length



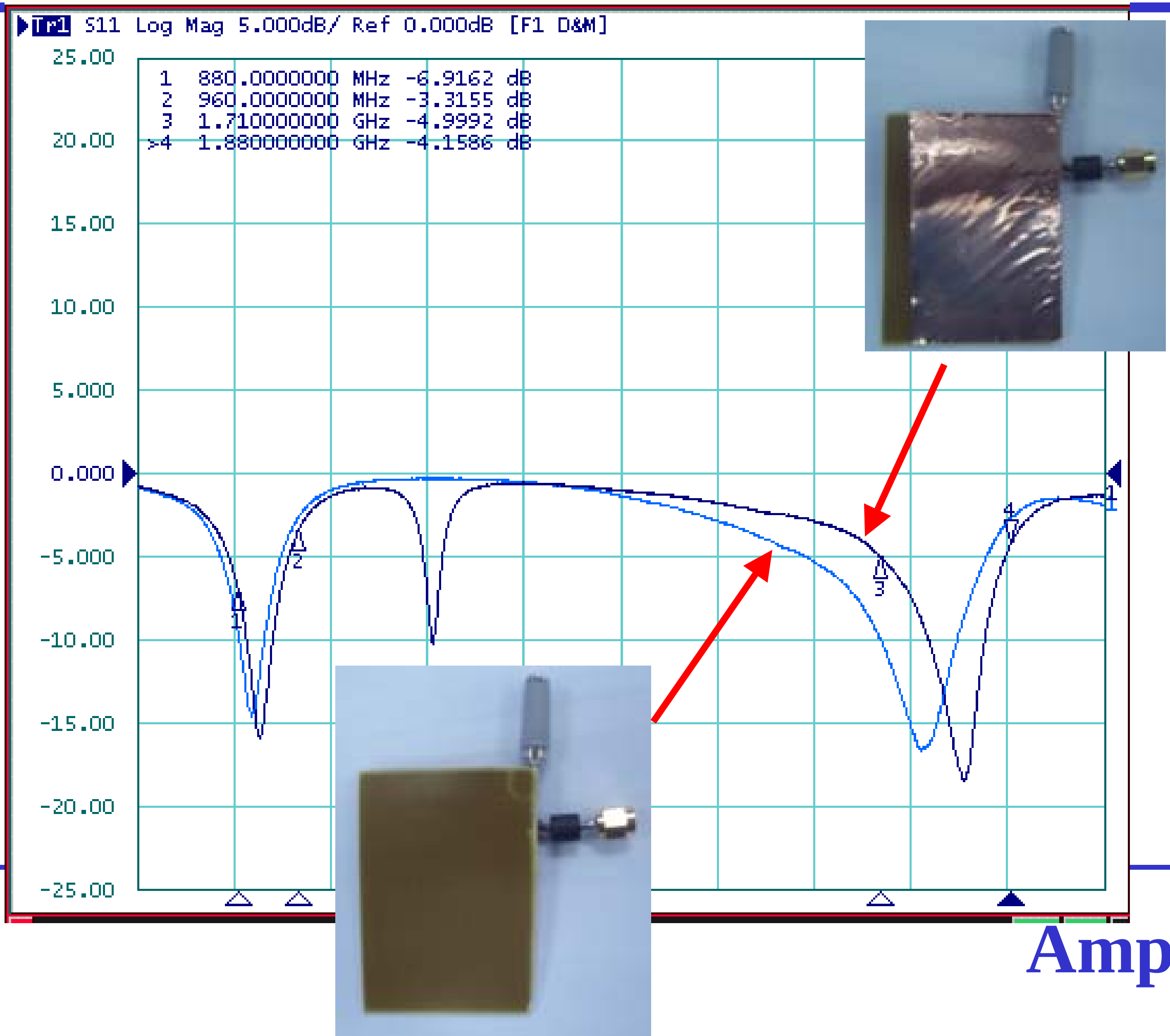
2.3 Influence of Handset design On Stubby Antenna



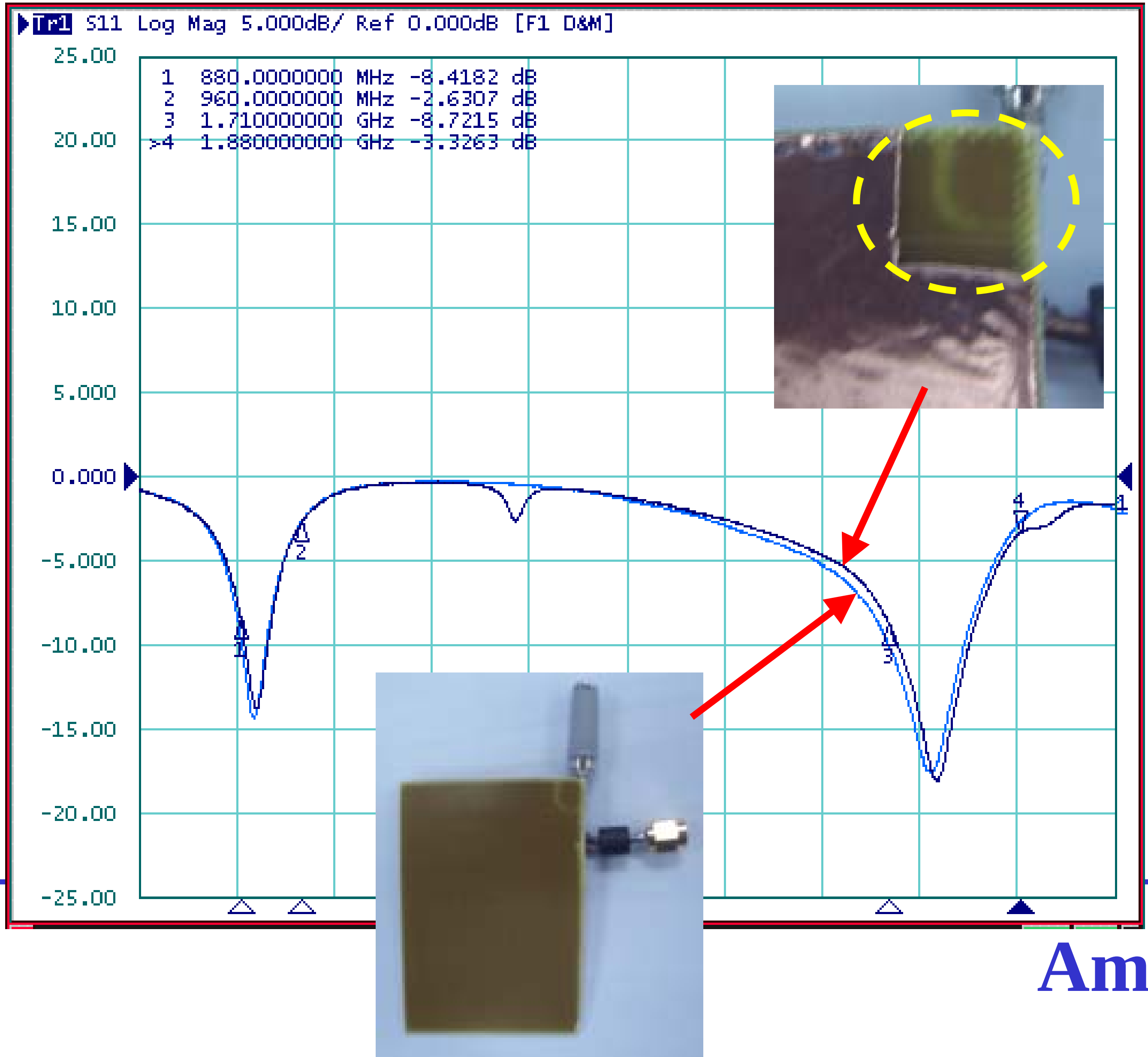
Pad and the ground



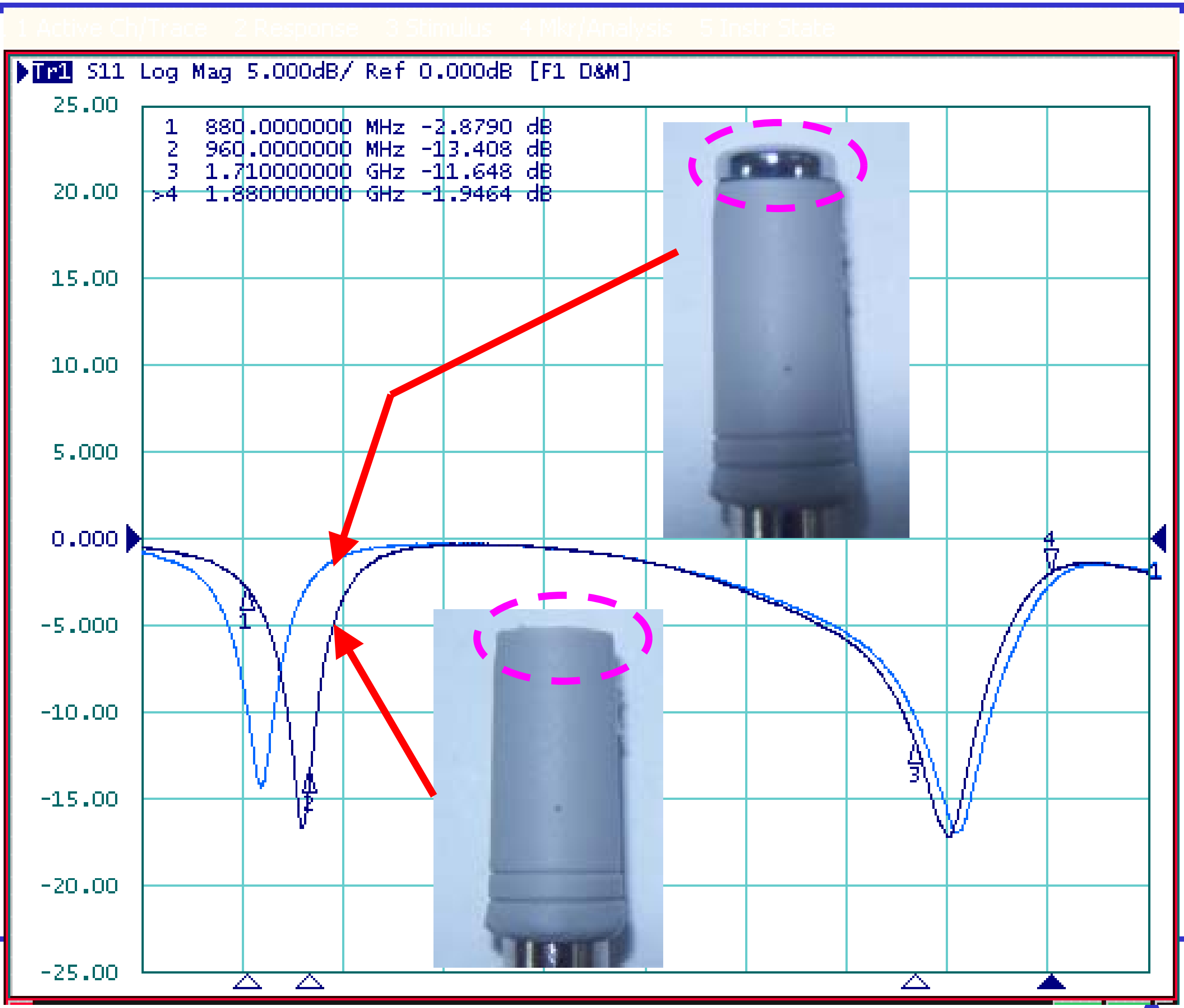
Ground (1)


Tr1 S11 Log Mag 5.000dB/ Ref 0.000dB [F1 D&M]
25.00
20.00
15.00
10.00
5.000
0.000
-5.000
-10.00
-15.00
-20.00
-25.00
1 880.0000000 MHz -6.9162 dB
2 960.0000000 MHz -3.3155 dB
3 1.710000000 GHz -4.9992 dB
>4 1.880000000 GHz -4.1586 dB

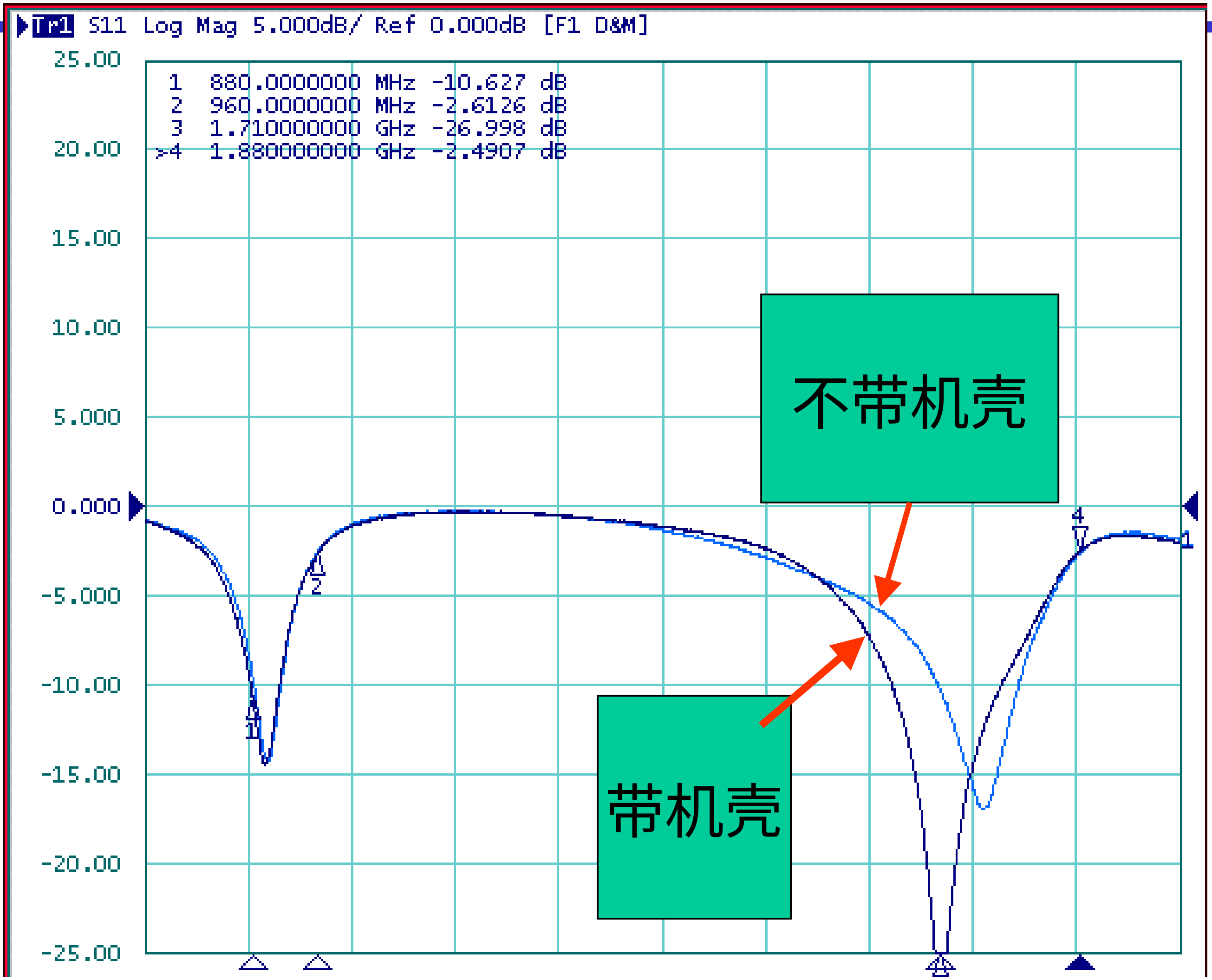
Ground (2)


Tr1 S11 Log Mag 5.000dB/ Ref 0.000dB [F1 D&M]
1 880.0000000 MHz -8.4182 dB
2 960.0000000 MHz -2.6307 dB
3 1.710000000 GHz -8.7215 dB
>4 1.880000000 GHz -3.3263 dB
25.00
20.00
15.00
10.00
5.000
0.000
-5.000
-10.00
-15.00
-20.00
-25.00

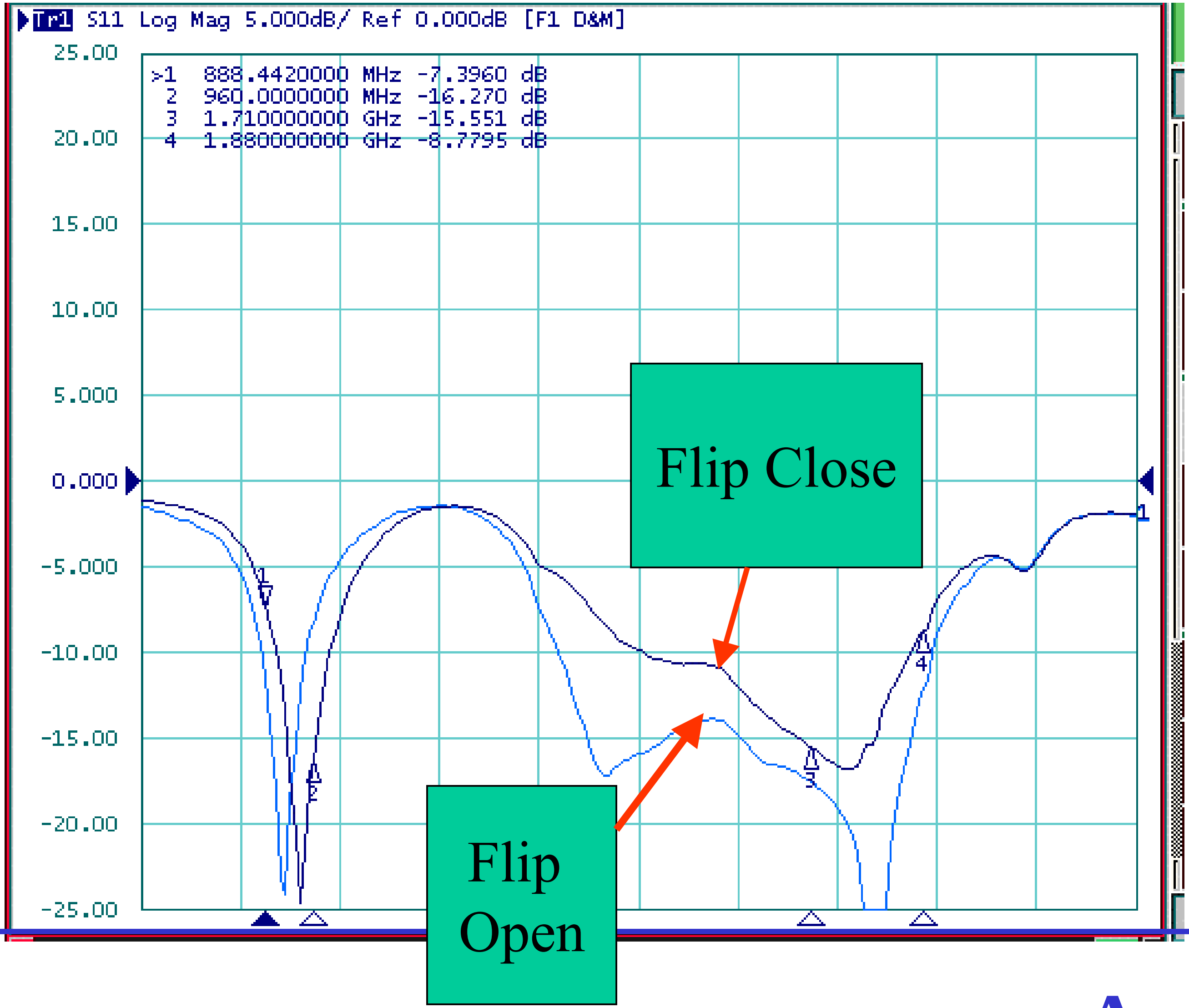
Cap


Tr1 S11 Log Mag 5.000dB/ Ref 0.000dB [F1 D&M]
1 880.0000000 MHz -2.8790 dB
2 960.0000000 MHz -13.408 dB
3 1.710000000 GHz -11.648 dB
>4 1.880000000 GHz -1.9464 dB
25.00
20.00
15.00
10.00
5.000
0.000
-5.000
-10.00
-15.00
-20.00
-25.00

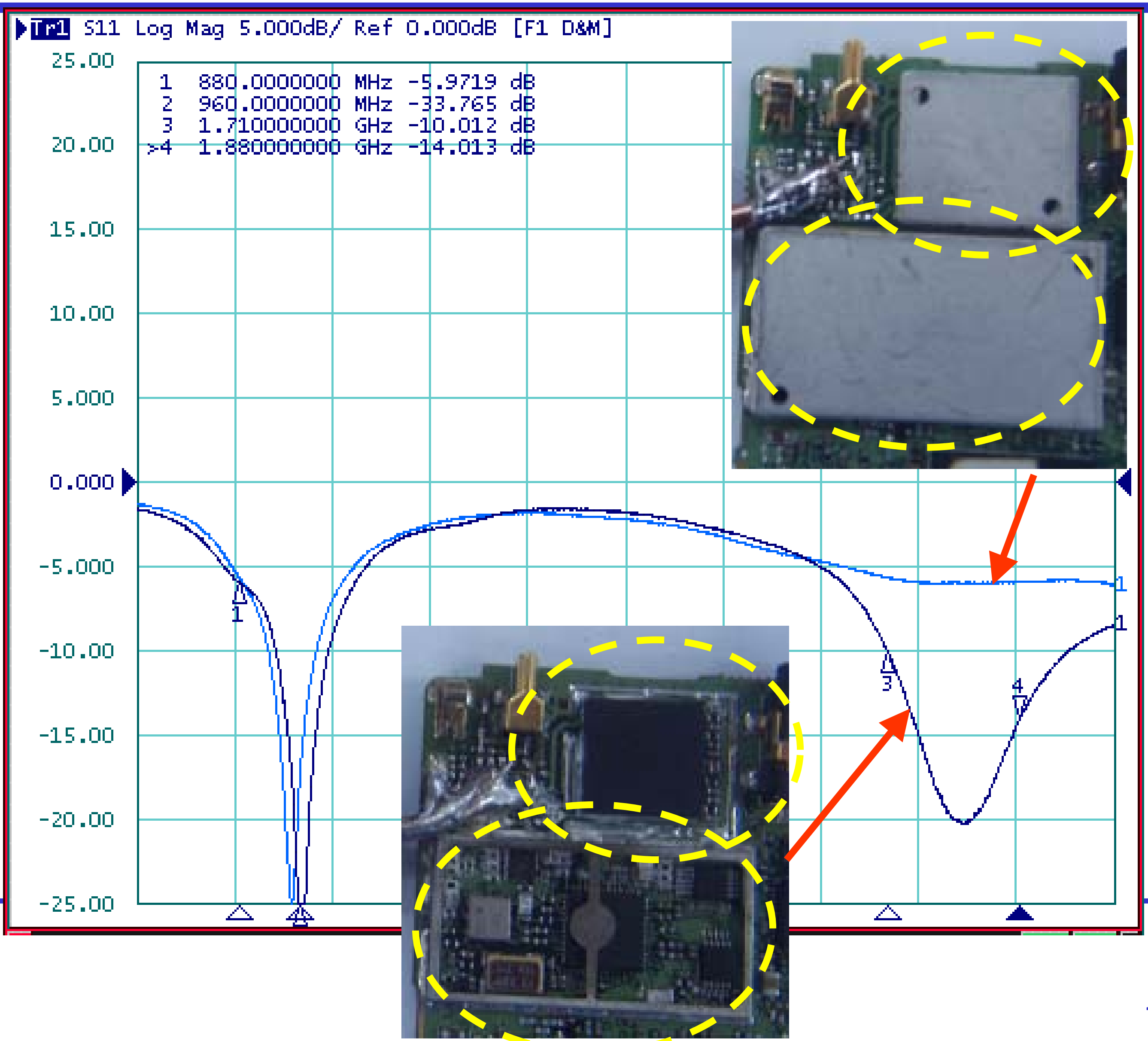
机壳


Tr1 S11 Log Mag 5.000dB/ Ref 0.000dB [F1 D&M]
1 880.0000000 MHz -10.627 dB
2 960.0000000 MHz -2.6126 dB
3 1.710000000 GHz -26.998 dB
>4 1.880000000 GHz -2.4907 dB
25.00
20.00
15.00
10.00
5.000
0.000
-5.000
-10.00
-15.00
-20.00
-25.00
不带机壳
带机壳

Flip Open and Close



Shielding



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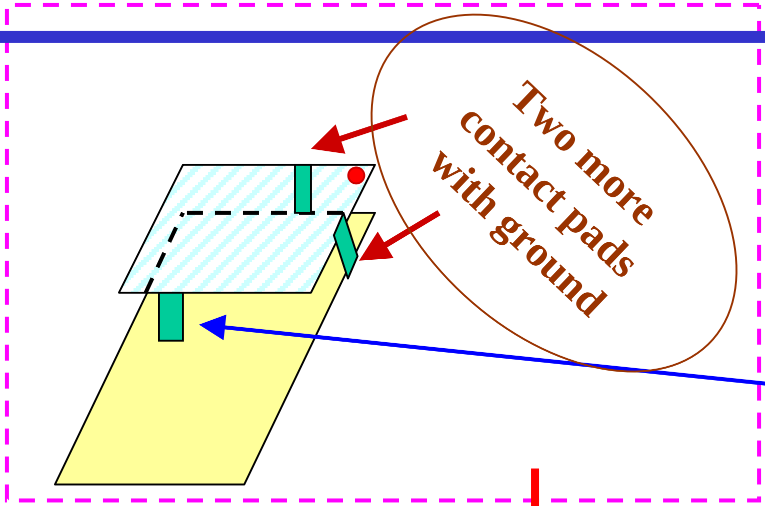
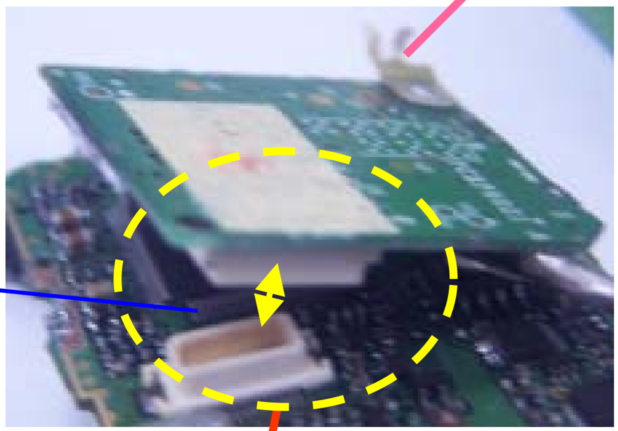
Contact with ground





Frequency(GHz) (PHS)	Gain(dB) (add two contact pads with ground)	Gain(dB) (One contact pad with ground)
1.895	2.52	-0.44
1.906	2.8	-0.16
1.918	2.52	-0.5

3 Conclusions

Conclusions For ME

Conclusions For PL

Conclusions For Customers

3 Conclusions

Conclusions For ME

- When mechanical engineers get the first mechanical drawings from the customers, MEs must discuss with RF engineers about the coil dimensions. Reason: The coil dimension greatly influence the RF performance.
- Pls inform RF engineers any change of mechanical design, including: materials, structures and dimensions.
- When making samples, MEs should participate in it to find the possible problems.
- Keep the length of cap as short as possible.
- Keep the size of bush as small as possible, like diameter, length etc..

3 Conclusions(2)

Conclusions For PM

- When PLs get a project, please ask the customers for the information of frequency band and matching circuits. And try your best to get the right to change the matching circuits.
- The change of handset usually will possibly influence the RF performance. Accordingly the antenna design will be changed. Hence PLs should positively grasp the information of handset change.
- To push the customers to feed back as soon as possible.
- Before mass production, the coils for mass production must be confirmed by the test.
- To give more time for RF engineers.

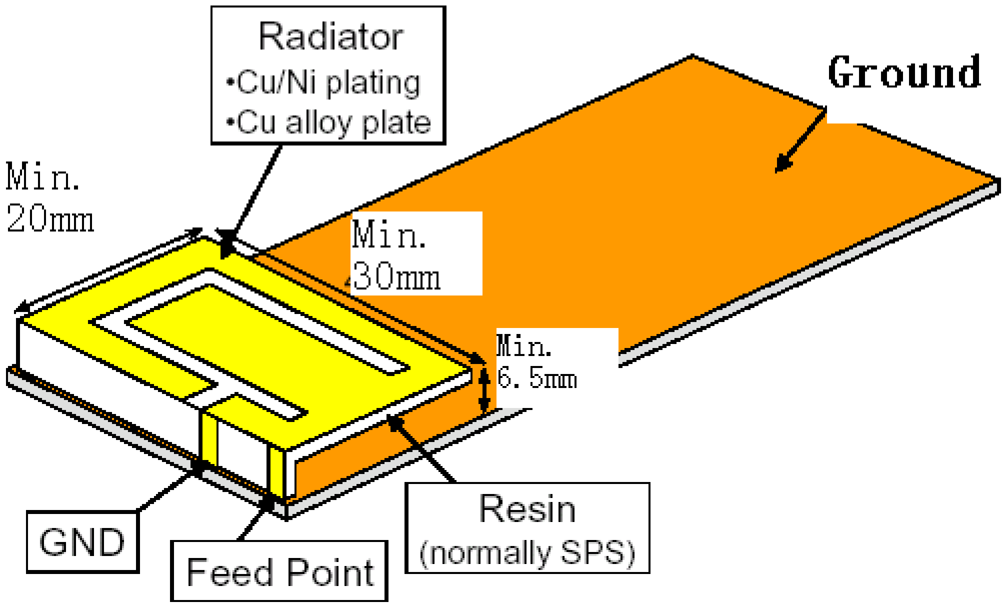
3 Conclusions(3)

Conclusions For Customers

- To provide a complete handset as possible.
- To inform antenna engineers when any change.
- To inform antenna engineers with the customers' test results as soon as possible.
- The performance of antenna is closely related with the handset itself. So the cooperation between the handset manufacturer and antenna manufacturer is important. The communication between them should be frequent.

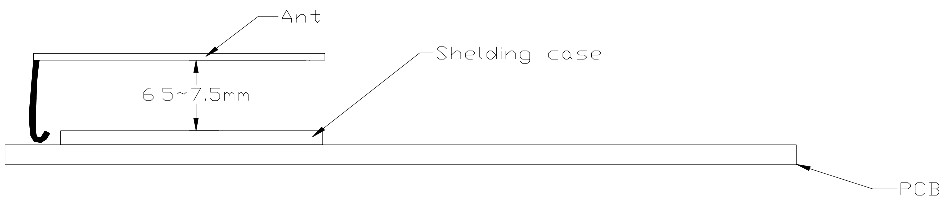
II.2 Internal Antenna

1 Dimension of Internal Antenna



2 Requirements for PCB

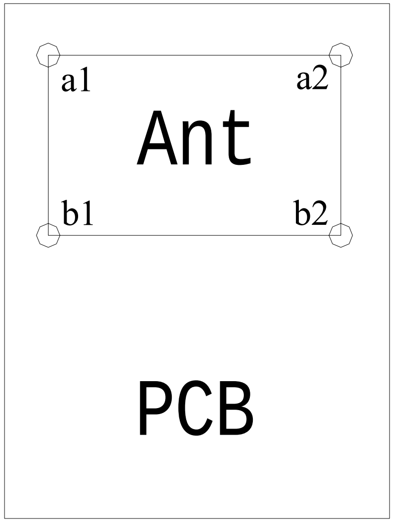
(1) The small components such as inductor, capacitor or RF-test connector can be put underneath the antenna.
(2) Everything connected to the baseband usually need to be shielded.
(3) The heights of the components must less than 1.5mm.
(4) If the important circuits or units under the antenna cause EMC, ESD and etc., please protect them with the shields.
(5) It is best to design the ground under the antenna as a whole part instead of some small blocks. .



(1) Because the shield under the antenna is treated as the extended ground, the height between the shield and the antenna still need to be 6.5—7.5mm.

(2) If there are small holes on the shield, their diameters must be less than $\lambda/50$.

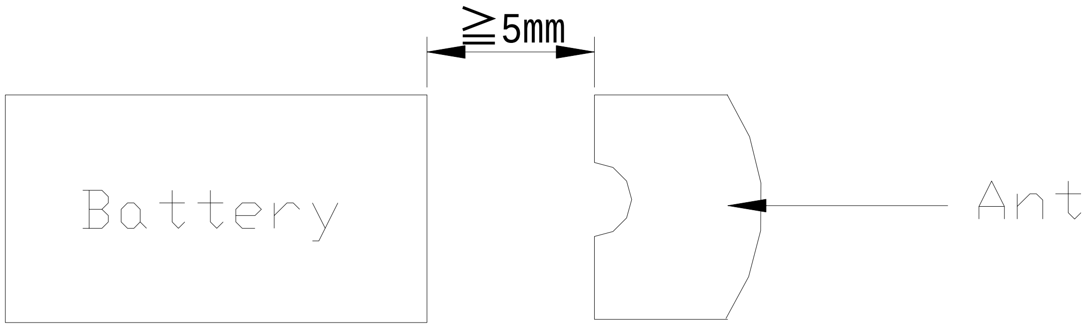
3 Feed Point and Ground Touch Pad



(1) A1 and A2 are the best positions of the feed point and the ground touch pad. The secondary choices are B1 and B2. Please don't put them on the middle part of each boundary of the antenna.

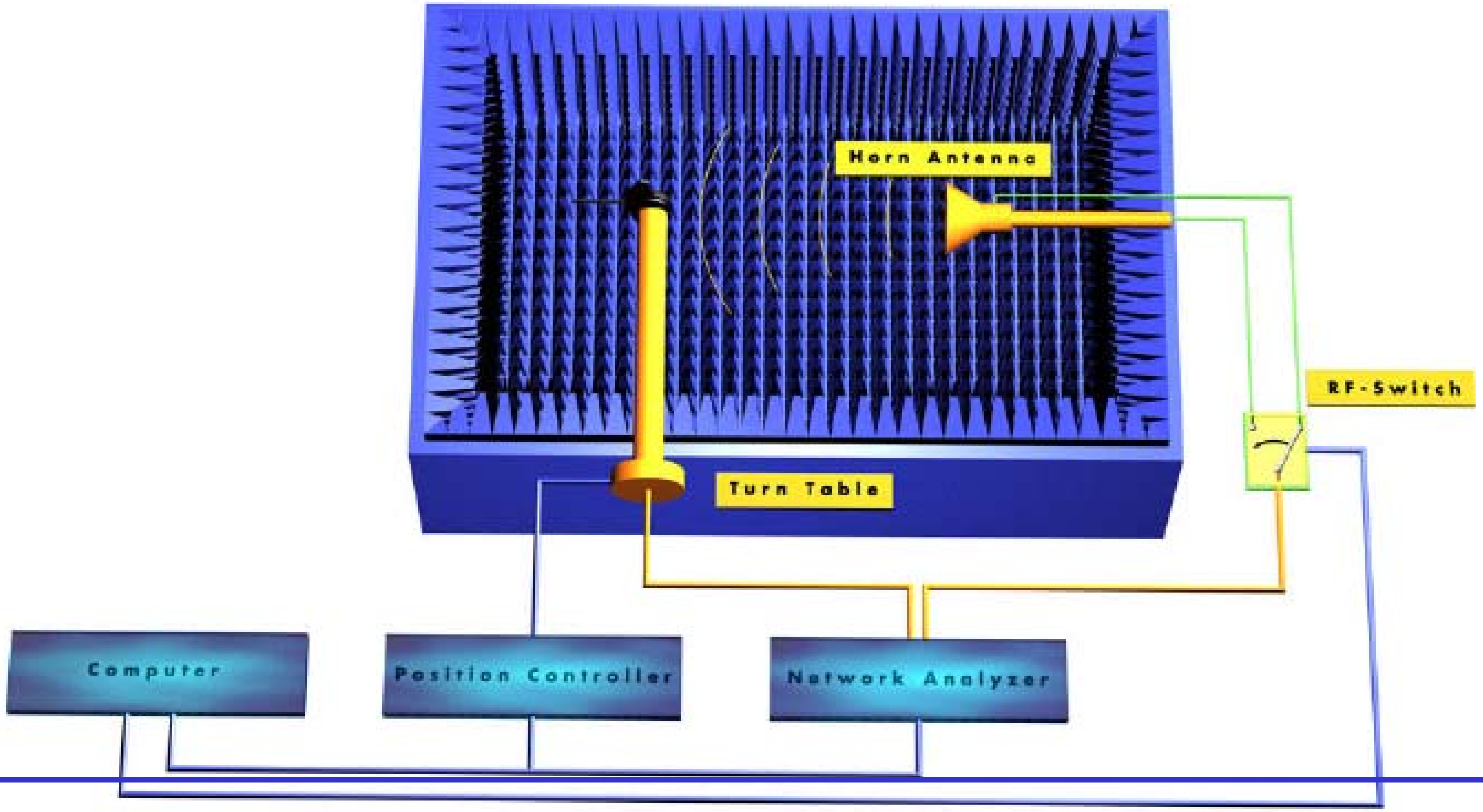
(2) The distance between the feed point and ground touch pad can not be so long. It will influence the VSWR and the bandwidth defined in terms of VSWR.

4 Antenna and Battery



Part III: Equipments

1 The structure of Anechoic Chamber



2 SAR Equipment: DASY4

3 Network Analyzers

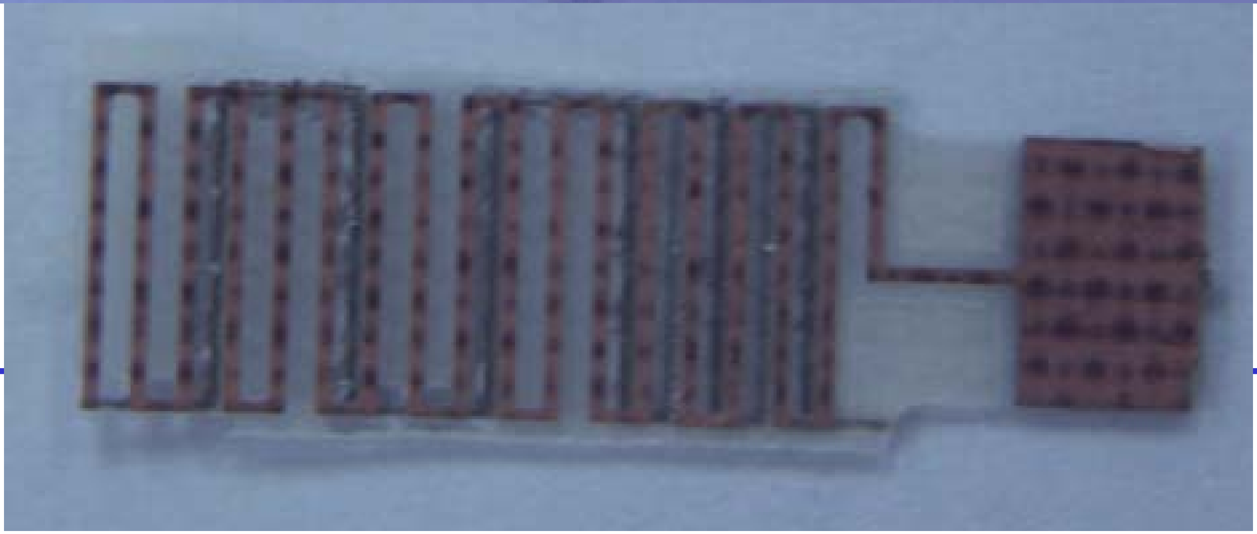
Agilent E5070B: 300kHz-3GHz: 2

Agilent E5071B: 300kHz-8.5GHz: 1

HP 8753ET: 300kHz-3GHz: 1

4 CMU 200

5 LPKF Circuit Board Plotter



Part IV: Summary

Capability to design PHS,CDMA single band antenna,
GSM/DCS dual band antenna,
GSM/DCS/PCS tri-band antenna,
WLAN antenna
Bluetooth antenna

Capability to design stubby antenna, retractable antenna, internal antenna

Capability to design antennas for mobile handset, PDA, smart phone, Pocket PC, Laptop and other small mobile terminals.

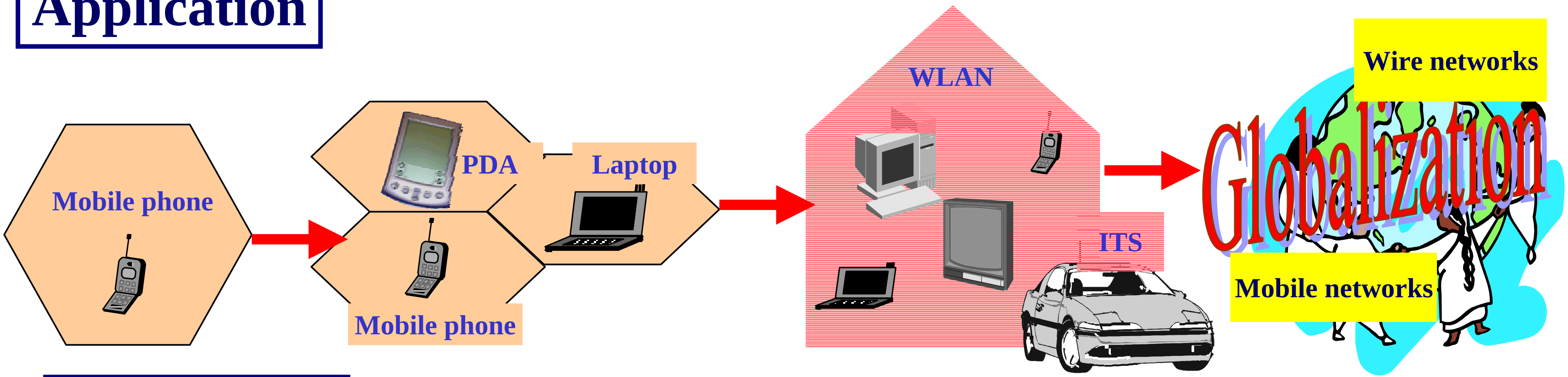
Let the customers know: Always consider the antenna early in the implementation process.

Well-equipped measurement systems:
2D,3D Chamber
Network Analyzers
LPKF ProtoMat C100/HF Circuit Board Plotter (for internal antennas)
SAR Test Centre:DASY4
CMU system (to simulate basestation)

Good quality and high RF performance:
VSWR
Gain
Low-cost and durable
ISO9001

Future Antennas

Application



Antennas

Monopole
Dipole
Helix
PIFA
Chip antenna
Patch
Meander line

Small
Light
Low-cost

→

Monopole
Dipole
Helix
Internal antenna
Chip antenna

Wideband
Multiband

Small
Light
Low-cost

→

Internal antenna
Ultra-wide Band antenna
Diversity antenna
Adaptive antenna
Integrated antenna system
Multi-antenna systems

Function:
Interference rejection
Adaptive control

Wideband
Multiband

Small
Light
Low-cost

→

Integrated antenna system
Adaptive antenna
Software Antenna

Intelligence

Function:
Interference rejection
Adaptive control

Wideband
Multiband

Small
Light
Low-cost

Future Antenna

Thank you!