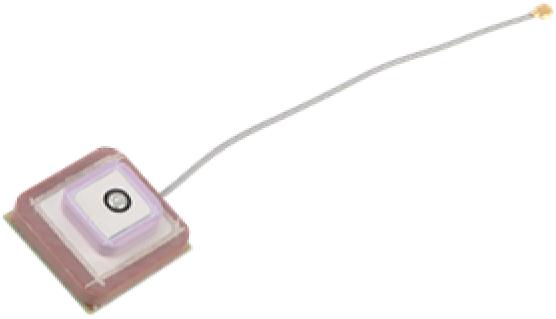
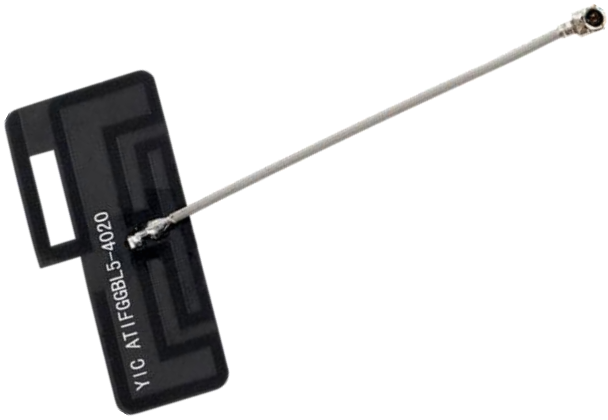
YIC





RF Antennas Introduction And Application

www.yic.com.tw

Directory

1. Product Information

1.1 Antenna Overview

An antenna is a device used to transmit or receive radio frequency (RF) waves. It radiates signals outward in the form of electromagnetic waves or couples incoming signals into the system. Therefore, an antenna is an essential component in a radio communication system。

All wireless equipment such as communication, radar, navigation, broadcasting, and television systems—transmit information via radio waves, and thus require the radiation and reception of these waves. This illustrates the critical importance of antennas in communication。

1.2 How Antennas Propagate

An antenna is essentially an energy converter for electromagnetic waves. A transmitting antenna converts high-frequency voltage and current into radio waves, while a receiving antenna converts radio waves into high-frequency voltage and current。

An antenna itself is a conductor. When alternating current flows through the conductor, it generates alternating electric and magnetic fields that propagate into space. The propagation of these alternating electromagnetic fields into space is known as electromagnetic wave radiation。

However, whether significant radiation can be achieved or whether the conductor can function as a high-performance antenna depends on the shape and size of the conductor。

As shown in Figure 1-a, when the distance between the two conductors is very small, the electric field is confined between them, resulting in very weak radiation。

When the two conductors are spread apart, as shown in Figure 1-b, the electric field disperses into the surrounding space, thereby increasing radiation。

When the two conductors are fully spread apart, as shown in Figure 1-c, the electric field fills the entire surrounding space, resulting in the strongest radiation。

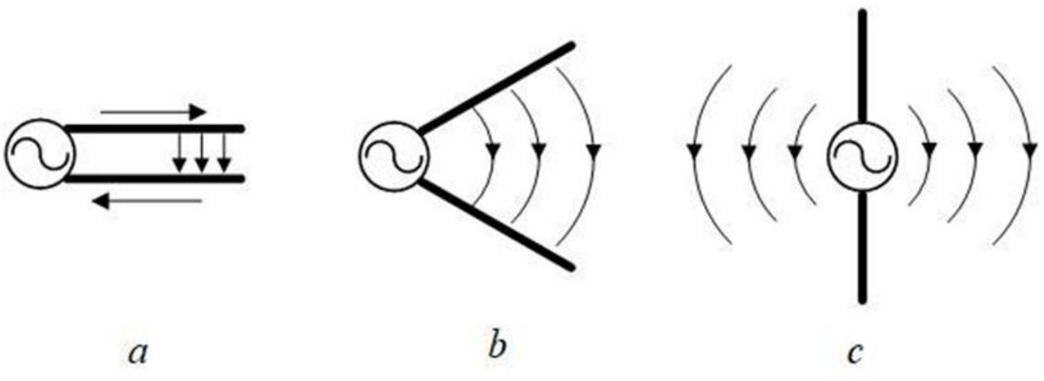
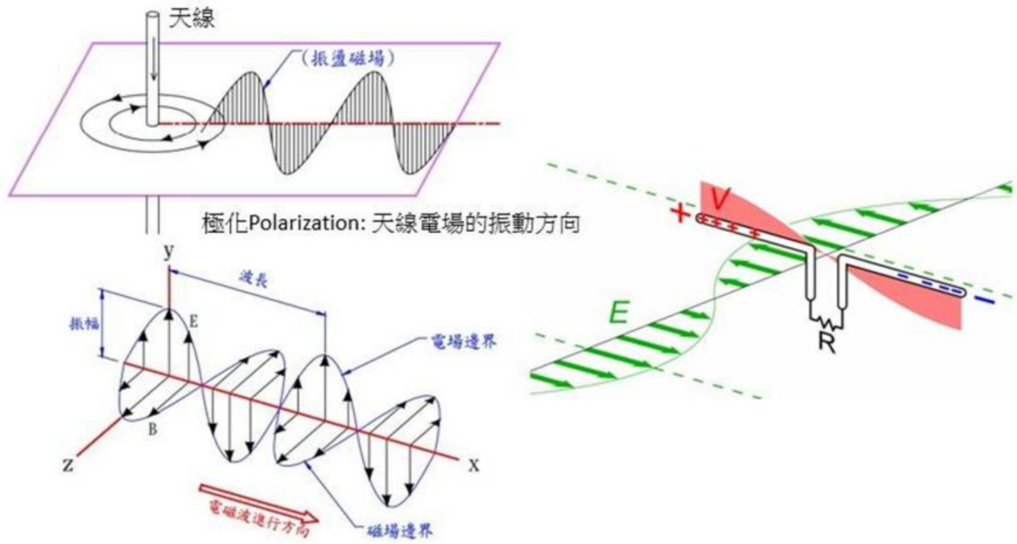


Figure 1 Schematic Diagram of Antenna Radiation Principle



It should be noted that when the length L of the conductor is much smaller than the wavelength λ, the radiation is very weak. As the length L increases to become comparable to the wavelength, the current on the conductor increases significantly, thereby enabling stronger radiation。

By comparing with a resonant circuit, it can be seen that when a receiving antenna resonates at a certain frequency, the electromagnetic wave of that frequency can induce a larger current in the antenna, allowing the receiver to easily "detect" it among many signals. When a transmitting antenna resonates at a certain frequency, the transmitter can drive the current in the antenna to its maximum, thus enabling the most efficient signal transmission。

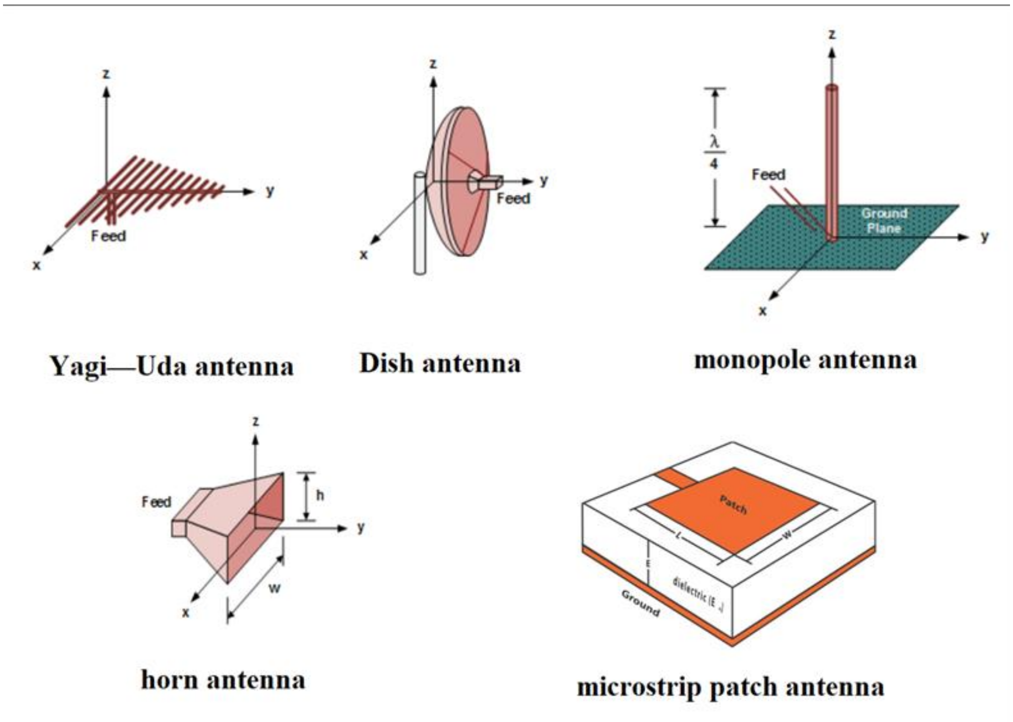
Similar to an RLC resonant circuit, when an antenna resonates, it is equivalent to a pure resistor. This resistance consists of two parts: the radiation resistance and the loss resistance of the antenna. According to Ohm's law, when the current is constant, the greater the radiation resistance, the higher the transmission efficiency. The value of the radiation resistance depends on the structural design of the antenna。

Loss resistance is undesirable; therefore, antennas should be made from materials with high conductivity and as large a surface area as possible to minimize loss resistance. At resonance, the resistance of the antenna is also its characteristic impedance, which is an important parameter to understand when using an antenna。

1.3 Antenna Classification

There are many types of antennas, and different classification methods can yield different categories。

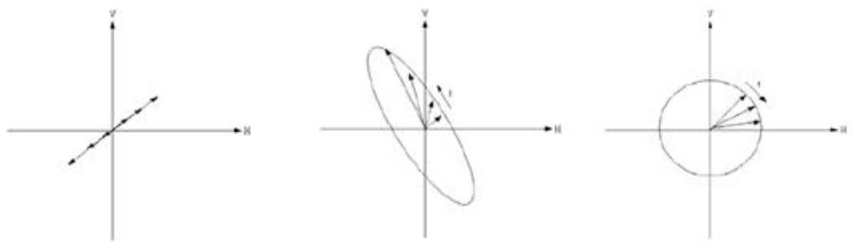
- By operating function, antennas can be classified into transmitting antennas and receiving antennas。
- By application, antennas can be classified into communication antennas, broadcasting antennas, television antennas, radar antennas, GPS antennas, and others。
- By directivity, antennas can be classified into omnidirectional antennas and directional antennas, such as patch antennas and Yagi antennas。
- By operating wavelength, antennas can be classified into ultra-long wave antennas, long wave antennas, medium wave antennas, short wave antennas, ultra-short wave antennas, and microwave antennas。
- By dimensionality, antennas can be classified into two types: one-dimensional antennas and two-dimensional antennas。
- By usage scenario, antennas can be classified into handheld antennas, vehicle antennas, base station antennas, and others. 。



1.4 Antenna Polarization

For an electromagnetic wave, its polarization state is defined by observing the relationship between the instantaneous electric field vector at a fixed point in space and its variation over time。

As the instantaneous electric field vector changes with time, the trajectory traced by the tip of the vector such as shown in Figure 2.1 represents the polarization state of the electromagnetic wave。



(a) 線性極化　(b) 橢圓極化　(c) 圓極化

Figure 2-1 Relationship Between the Instantaneous Electric Field Vector and Time for Different Polarization States

1.4.1 Linear Polarization

When the tip of the electric field vector varies over time and traces a straight line on a plane, the electromagnetic wave is defined as linear polarized, as shown in Figure 2.1(a). A linear polarization is typically defined with reference to a plane, often using the Earth’s surface as the reference plane。

For a horizontally polarized electromagnetic wave, the electric field vector oscillates parallel to the Earth’s surface. Conversely, if an electromagnetic wave is defined as vertically polarized, its electric field vector has only a component perpendicular to the Earth’s surface。

Any electromagnetic wave in space can be decomposed into two orthogonal linear polarizations. If these two orthogonal linear polarizations have the same phase variation, the resulting electromagnetic wave will also be a linear polarization, as shown in Figure 2.1(a) 。

1.4.2 Elliptical Polarization

When two orthogonal linear polarizations in space are not in phase, the resultant electric field vector will rotate in a specific direction over time, with its amplitude varying periodically, as shown in Figure 2.1(b). In this case, the tip of the electric field vector traces an ellipse over time, and the shape of the ellipse is determined by the amplitudes of the two orthogonal linear polarization vectors and their phase difference. The axial ratio is defined based on the ratio of the major axis to the minor axis of this ellipse, as follows:

$$|R| = \frac{\textit{major axis}\ \text{length}}{\text{minor axis length}}\text{ , }\mathrm{R} = 20\log|\mathrm{R}|\ \mathrm{dB}$$

The axial ratio is often used to determine the polarization state of an electromagnetic wave. For example, when the axial ratio is 1, it indicates that the electromagnetic field in space is circularly polarized. When the axial ratio is 0 or infinitely large, it indicates that the electromagnetic field in space is linearly polarized。

1.4.3 Circular Polarization

When two orthogonal vectors in space have the same amplitude and a phase difference of 90 degrees, the polarization state is circular polarization. Circular polarization can be further classified into Left-Hand Circular Polarization (LHCP) and Right-Hand Circular Polarization (RHCP), based on the trajectory of the electric field vector tip over time。

From the observer' s perspective, if the direction of electromagnetic wave propagation is toward the observer and the trajectory of the electric field vector tip rotates counterclockwise over time, the wave is defined as Right-Hand Circular Polarization (RHCP). Conversely, if under the same observation conditions the trajectory rotates clockwise, the wave is defined as Left-Hand Circular Polarization (LHCP) 。

Mathematical derivation is as follows。Observe, in a plane, the trajectory of the tip of the electric field vector, and assume the electric field is given by:

$$\vec{E} = E_{0x} e^{-jkz} \hat{a}_x + E_{0y} e^{-jkz} * e^{j\phi} \hat{a}_y$$
$$= E_{0x} \cos(wt - kz) \hat{a}_x + E_{0y} \cos(wt - kz + \phi) \hat{a}_y$$

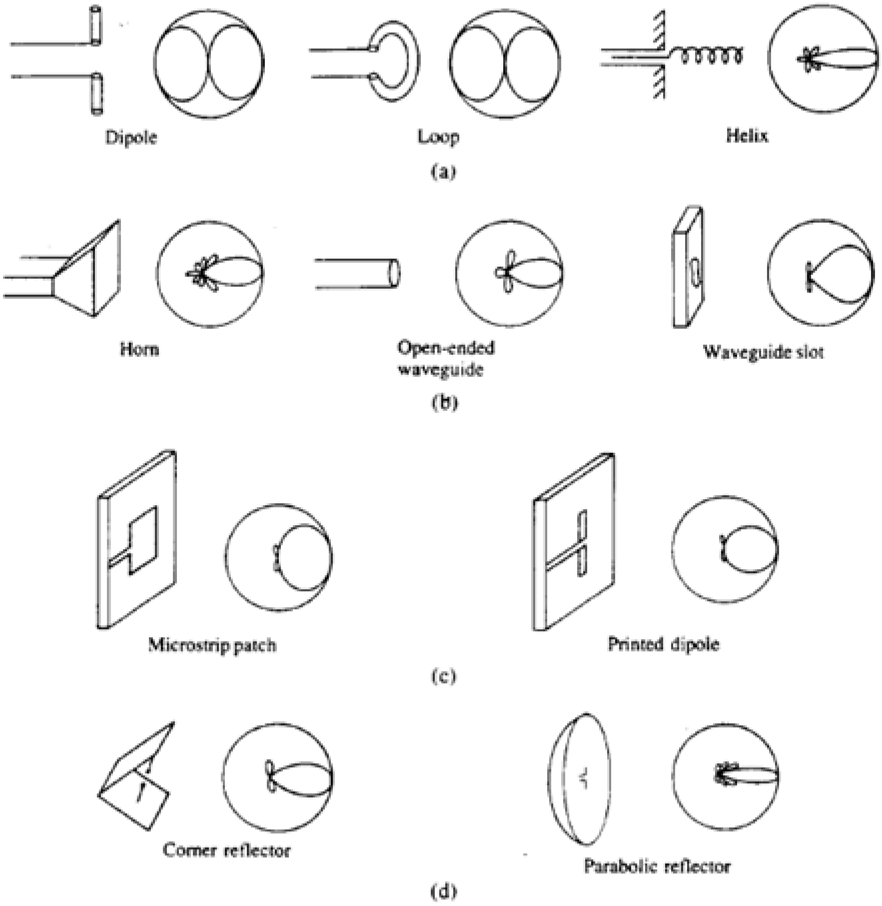
Consider the plane Z=0:

$$\vec{E}(z=0) = E_{0x} \cos(wt) \hat{a}_x + E_{0y} \cos(wt + \phi) \hat{a}_y$$

When two orthogonal field components have equal amplitudes and a 90° phase difference, $E_{0x}=E_{0y}$ and let $\varphi = 90^\circ$, then, observed on the plane z=0, the electric field is::

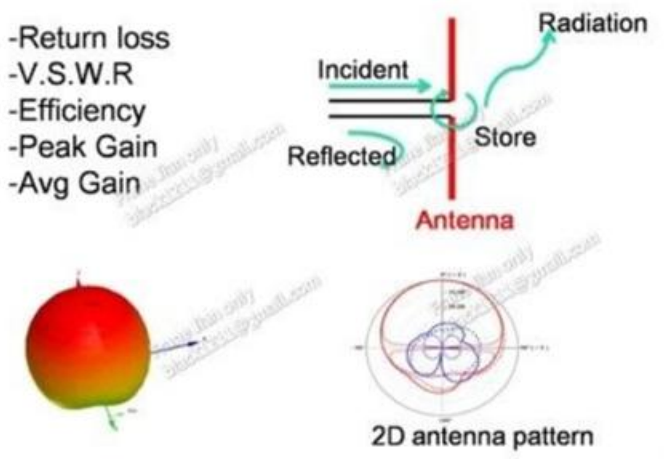
$$\vec{E}(z=0) = E_0 \cos(wt) \hat{a}_x + E_0 \cos(wt + 90) \hat{a}_y$$
$$= E_0 \cos(wt) \hat{a}_x - E_0 \sin(wt) \hat{a}_y$$

At this point, the trajectory of the electric field vector tip observed on the plane z=0 is as shown in Figure 2.1(c)，It is a Left-Hand Circular Polarization (LHCP)，if $\varphi = -90^{\circ}$，the trajectory of the electric field vector tip corresponds to a Right-Hand Circular Polarization (RHCP)。



Various Antenna Polarizations

1.5 Antenna Specifications



1.5.1 Antenna Power:

- Antenna power is measured in milliwatts (mW), where 1 milliwatt equals 1/1000 of a watt (0.001 watts)。
- For indoor Wi-Fi wireless networks, the typical power is 30 – 100 mW (with a maximum of 100 mW, capable of reaching up to 1 mile)。
- For outdoor point-to-point base station access points (AP), the power may exceed 100 mW, such as in a mesh network。
- Mobile phones adjust their power relative to the position of the base station, with GSM900 having a maximum of 2 W and GSM1800 having a maximum of 1 W。

1.5.2 Antenna Gain ：(db / dBm / dBi / dBd / dBic / dBdl / dBdc)：

(1) dB is a ratio, not a unit

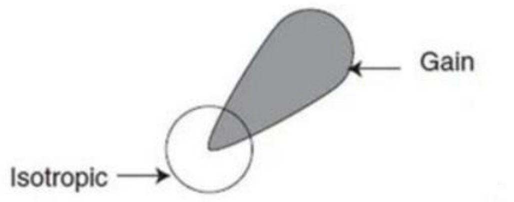
(2) dBm = 10 log10 (P mW / 1mW)

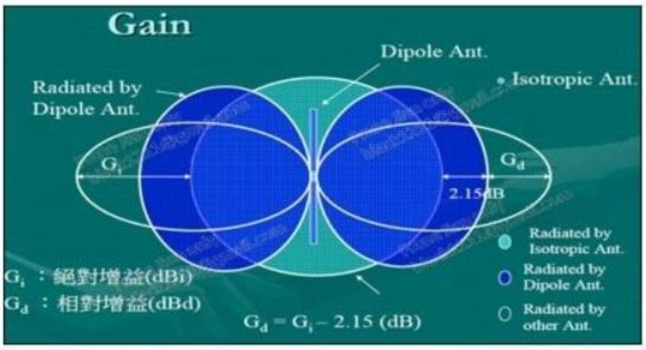
(3) dBi : Absolute gain = Relative gain + 2.15dB

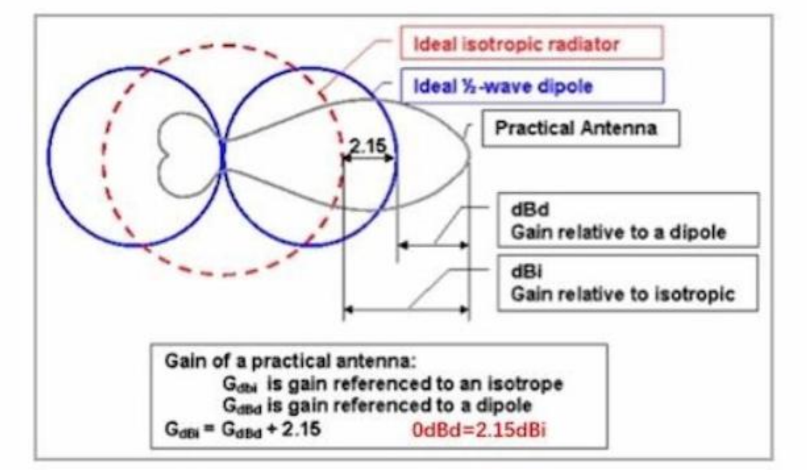
It refers to the gain/loss for antennas, measured relative to an isotropic antenna (antenna absolute gain)。

(4) dBd : Relative Gain

It is the measurement relative to a dipole antenna (antenna relative gain) and differs from the absolute gain by 2.15 dB。







(5) dBic : It represents the gain relative to an isotropic antenna with circular polarization

(6) dBdl : It represents the gain relative to a dipole antenna with linear polarization

(7) dBdc : It represents the gain relative to a dipole antenna with circular polarization

1.5.3 VSWR:

- Standing Wave

In general, the electromagnetic wave on a transmission line consists of a traveling wave (forward-propagating wave) and a reflected wave。

When the incident wave and the reflected wave combine to form peaks (maximum absolute value) and nodes (zero points) whose positions remain fixed, varying only in amplitude over time, the resulting wave is called a standing wave。

Once a standing wave is formed inside the transmission line, the electromagnetic wave cannot be effectively transmitted. The wavelength at which a standing wave is formed is exactly the wavelength of the electromagnetic wave generated or received by the antenna。

- Standing Wave Ratio (SWR) Formula

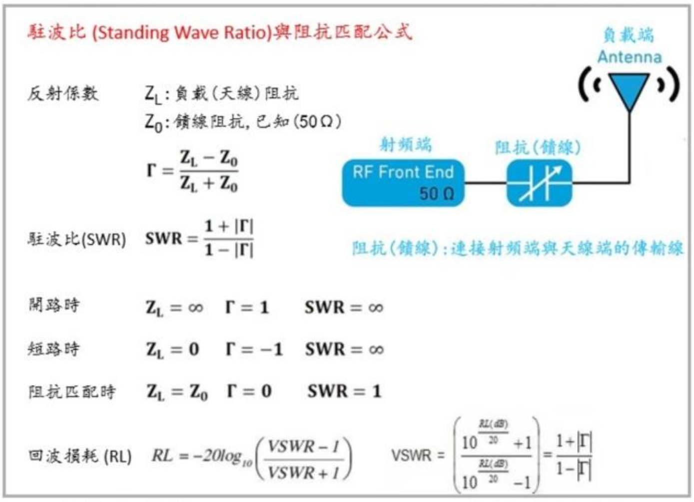
It refers to the ratio of the voltage amplitude at the antinode (wave crest) to that at the node (wave trough) of a standing wave, also known as the standing wave coefficient or standing wave ratio (SWR)。

- Reflection Coefficient

The quantity used to measure the magnitude of reflection is called the reflection coefficient, commonly denoted by Γ. For simplicity, let us assume the load impedance is purely resistive. The reflection coefficient Γ is defined as the ratio of the reflected voltage wave to the incident voltage wave。

In a matched condition, all high-frequency electromagnetic energy flows into the load with no reflection. In this case, the voltage amplitude is equal at all positions along the transmission line, and no standing wave exists. This is referred to as the traveling wave state。

In a mismatched condition, the presence of a reflected wave causes it to combine with the forward wave, resulting in periodic variations in amplitude at different points along the line. This phenomenon is referred to as the standing wave state。



1.5.4 Impedance Matching:

The purpose of achieving complete impedance matching between the signal end (RF end) and the load end (antenna).

- To prevent the occurrence of standing waves

If the load impedance and the signal source impedance are not matched, a reverse wave will be generated, and part of the signal will be reflected back to the signal source. At this point, the forward wave and the reverse wave combine to form a standing wave (the signal stagnates and cannot be transmitted). Therefore, when the standing wave ratio (SWR) is 1, it indicates that no standing wave is generated, which also means complete impedance matching !

- Antenna Impedance Matching Adjustment: (smith chart)

A type of chart used in electronic engineering that allows engineers to solve problems related to transmission lines and impedance matching circuits. The Smith chart can display various parameters of an RF circuit in a graphical form。

The Smith chart is a mathematical transformation of the complex plane in a two-dimensional rectangular coordinate system. Impedance values with a positive real part (resistance) are mapped inside the chart’ s circle, while impedance values with a negative real part (resistance) are mapped outside the circle. In practice, attention is usually focused on the region inside the circle, as negative resistance cases are generally not considered. The mathematical transformation formula is:

$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{z-1}{z+1}$$

$$z = \frac{Z_L}{Z_0}$$

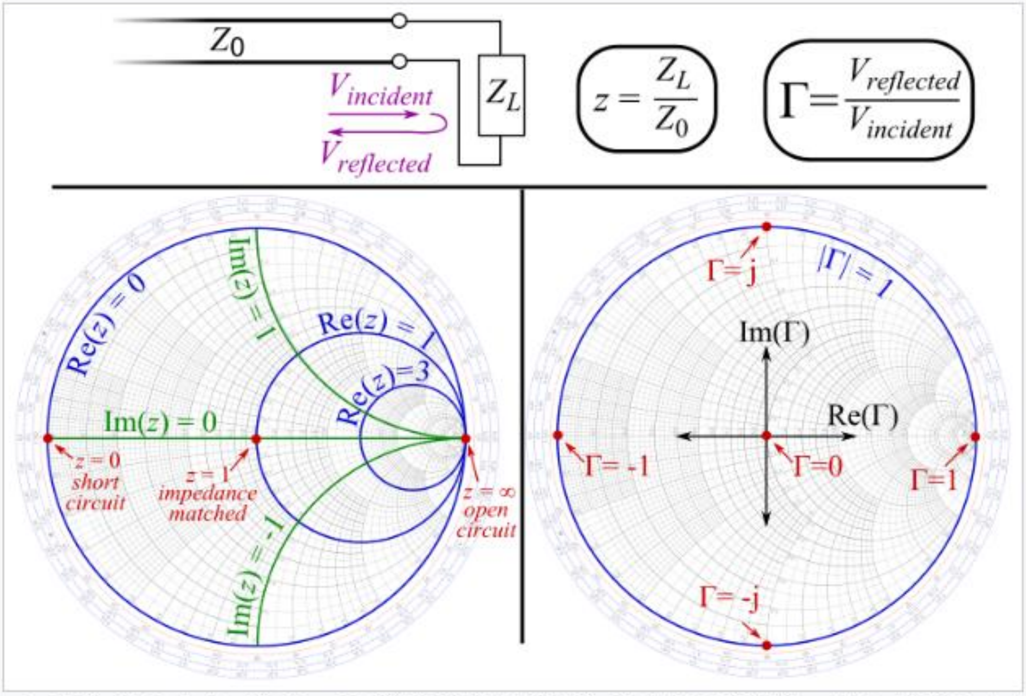
Γ represents the reflection coefficient of the line, which corresponds to S11S_{11}S11 in S-parameters. ZLZ_LZL is the load impedance of the circuit. Z0Z_0Z0 is the reference impedance (also called the system impedance), which is generally chosen to be the characteristic impedance of the transmission line under study—typically 50 Ω。

z is the normalized impedance. In other words, we divide the load impedance ZLZ_LZL of a circuit by the reference impedance Z0Z_0Z0, making the normalized impedance equal to 1, which is located at the origin of the chart。

The advantage of using normalized impedance is that the same Smith chart can be applied to various systems with different characteristic impedances。

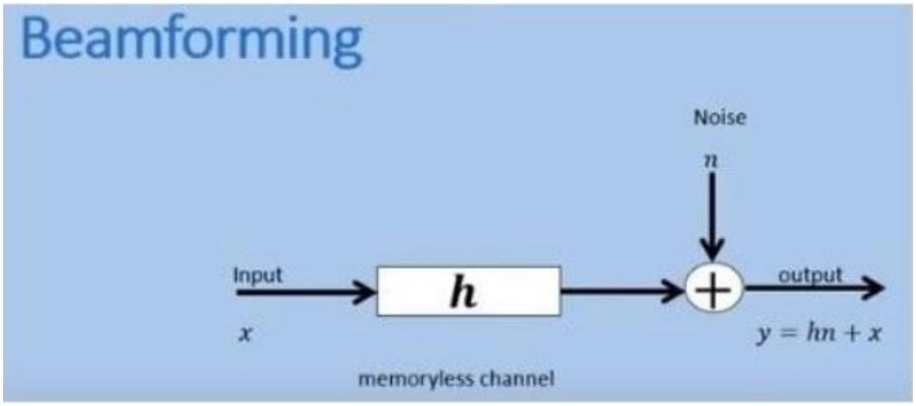
In the chart, the circular lines represent the real part of the impedance, i.e., the resistance value. The horizontal center line and the lines radiating upward and downward represent the imaginary part of the impedance, i.e., the reactance generated by capacitance or inductance at high frequencies. The upward direction corresponds to positive values, indicating an inductive load, while the downward direction corresponds to negative values, indicating a capacitive load。

The very center point of the chart (1+j0)(1 + j0)(1+j0) represents the reference impedance—meaning an impedance-matched resistance value (ZL=Z0Z_L = Z_0ZL=Z0)—and at this point, the reflection coefficient is zero. The edge of the chart represents a reflection coefficient magnitude of 1, which corresponds to 100% reflection. The numbers along the chart’s edge indicate the reflection coefficient angle (0–180 degrees) and the wavelength (from zero to half a wavelength)。



史密斯圖的基本使用方法。電磁波順著特性阻抗為Z_0的傳輸線前進，並在末端遇到以一阻抗為Z_L的負載（其歸一化阻抗為$z=Z_L/Z_0$）。此時信號會產生反射，其反射係數為Γ。史密斯圖上的任何一點同時表示阻抗值z（左圖）和對應的反射係數Γ（右圖）。兩者的關係式為$z=(1+\Gamma)/(1-\Gamma)$。

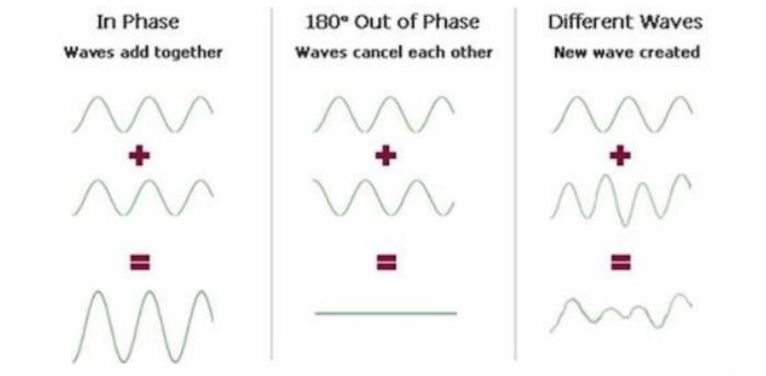
1.5.5 Beamforming



- In Phase 與 Out Phase

The signal amplitude oscillates back and forth between positive and negative values，When two signals vibrate in the same direction (in phase), they will reinforce each other。

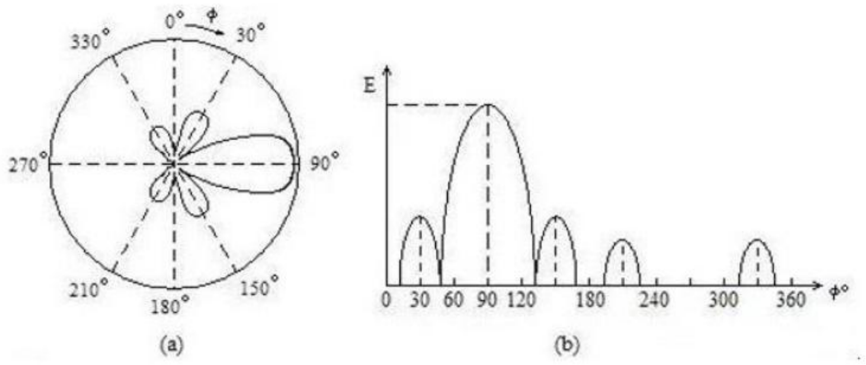
When two signals vibrate in opposite directions (out of phase) with a phase difference of exactly 180°, they will cancel each other out, resulting in no signal at all。



Only signals with the same phase angle will add together (while signals with opposite phase angles are canceled out), forming the strongest main lobe of the radiation pattern—this is the fundamental principle of array antennas。

- radiation pattern:

A diagram that represents the spatial distribution of the electromagnetic field strength radiated by an antenna, expressed through a mathematical function graph。The maximum radiation lobe is usually called the main beam。
The smaller lobes adjacent to the main beam are called side beams (or side lobes)。



(a)極座標表示　　　　　(a)直角座標表示

- Beamwidth

Beamwidth provides a measure of the antenna’s angular resolution. Most commonly, beamwidth is defined by the Half-Power Beamwidth (HPBW) or the First Null Beamwidth (FNBW), which is the spacing between the first nulls of the main lobe。

To determine HPBW, we move 3 dB down from the peak value and measure the angular distance, as shown in the figure.

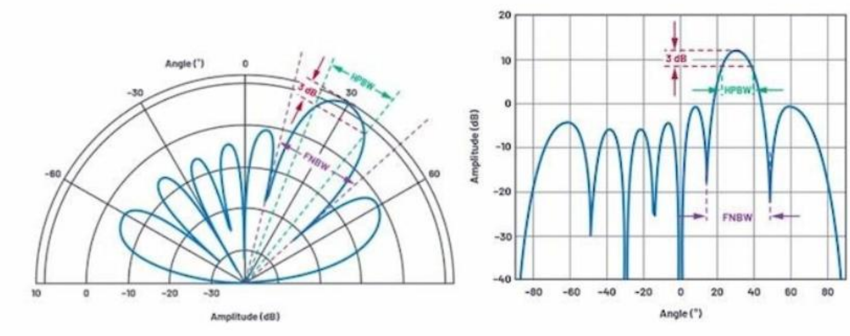


圖 N = 8，d = λ/2，θ = 30°的極座標天線方向性繪圖

1.5.6 Equivalent Isotropically Radiated Power

In an ideal situation, it is equal to the transmitter’s output power multiplied by the antenna’s gain。

$$EIRP = P_T * G_a$$

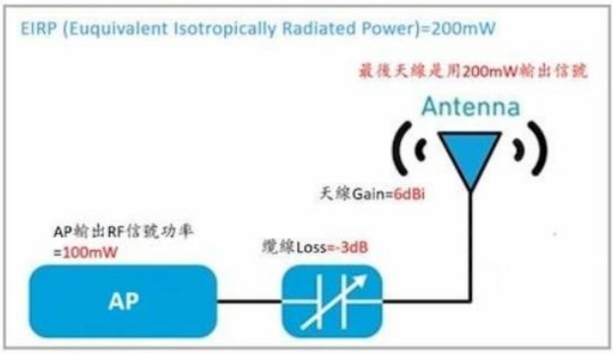
Where P_T represents the transmitter’s output power, and G_a represents the antenna’s gain。

When calculated in logarithmic form and taking feed line loss into account, it can be expressed as：

$$EIRP = P_T - L_c + G_a$$

The unit is **dBW**, and Lc represents the loss in the feed line

- For example, an RF signal with an output power of 100 mW from a base station (Access Point) experiences a 3 dB loss through the cable connection but gains 6 dBi from the RF antenna. As a result, the net signal gain is − 3 dB+6 dBi=3 dB-3\ \text{dB} + 6\ \text{dBi} = 3\ \text{dB}− 3 dB+6 dBi=3 dB. Therefore, the output at the antenna end is approximately 200 mW (since a 3 dB gain roughly doubles the power)。



If we wish to express this with a more precise formula, namely:

$\Delta P = 10 \times \log(Pf/Pi)$

→ $3\ dB = 10 \times \log(Pf/100)$

→ $Pf/100 = 10^{0.3}$

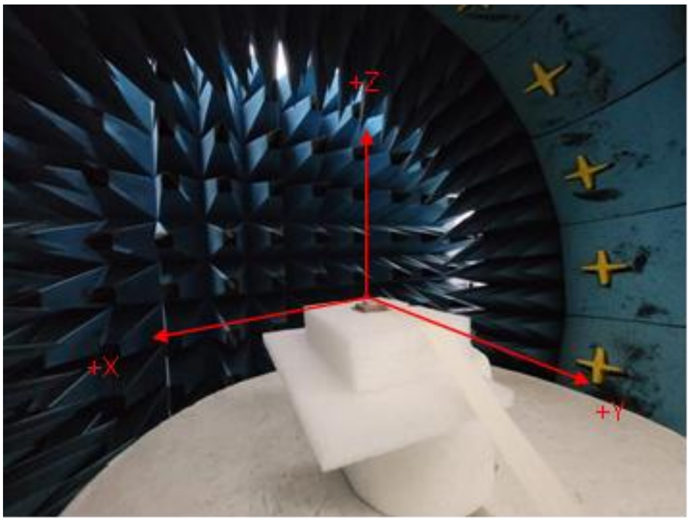
→ $Pf \fallingdotseq 200$

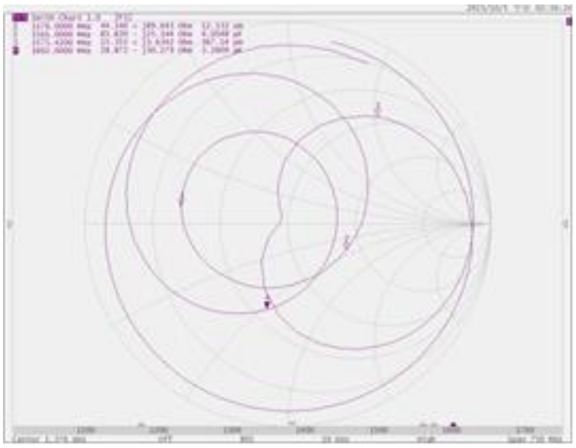
200mW is EIRP (Euquivalent Isotropically Radiated Power).

1.6 Antenna Tuning (ATPGGBL52580A)

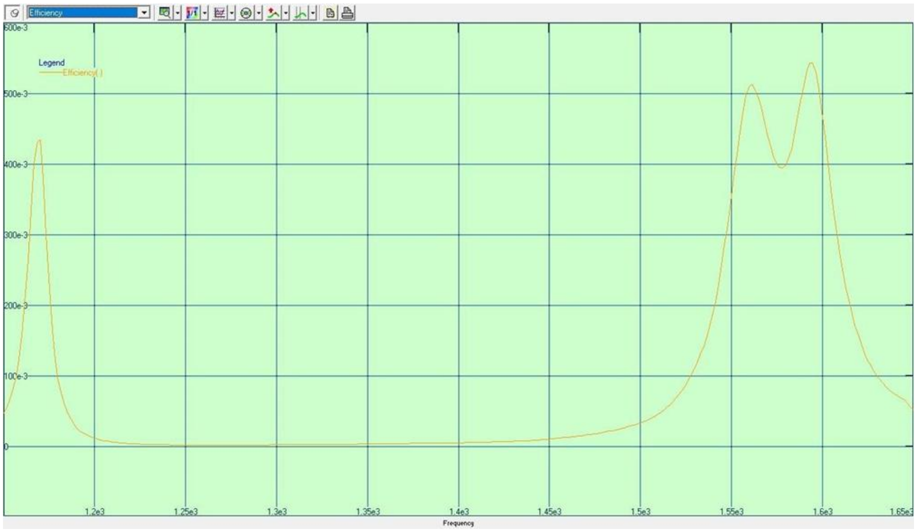
A good antenna requires continuous tuning to resonate at maximum power for optimal radiation. YIC offers customized antenna services。

The figure below shows a comparison before and after antenna tuning。



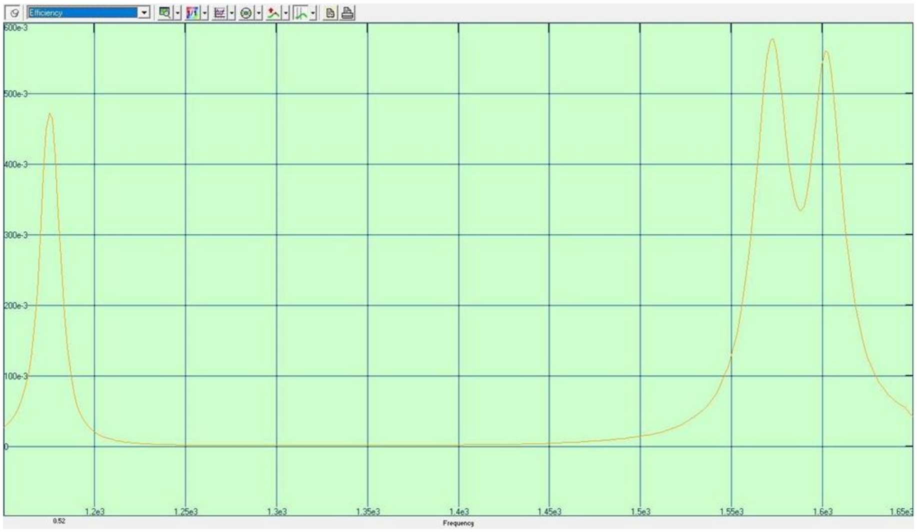


Before:(Efficiency)



Frequency	1176MHz	1561MHz	1575MHz	1602MHz
(Unit：dBic)	19	51	40	42

After: (Efficiency)



Frequency	1176MHz	1561MHz	1575MHz	1602MHz
(Unit：dBic)	46	30	55	56

Before:(Peak Gain)

Frequency	1176MHz	1561MHz	1575MHz	1602MHz
(Unit：dBic)	-6.74	-1	-1.89	-4.29

After: (Peak Gain)

Frequency	1176MHz	1561MHz	1575MHz	1602MHz
(Unit：dBic)	-1.43	-3.87	-0.52	-2.6

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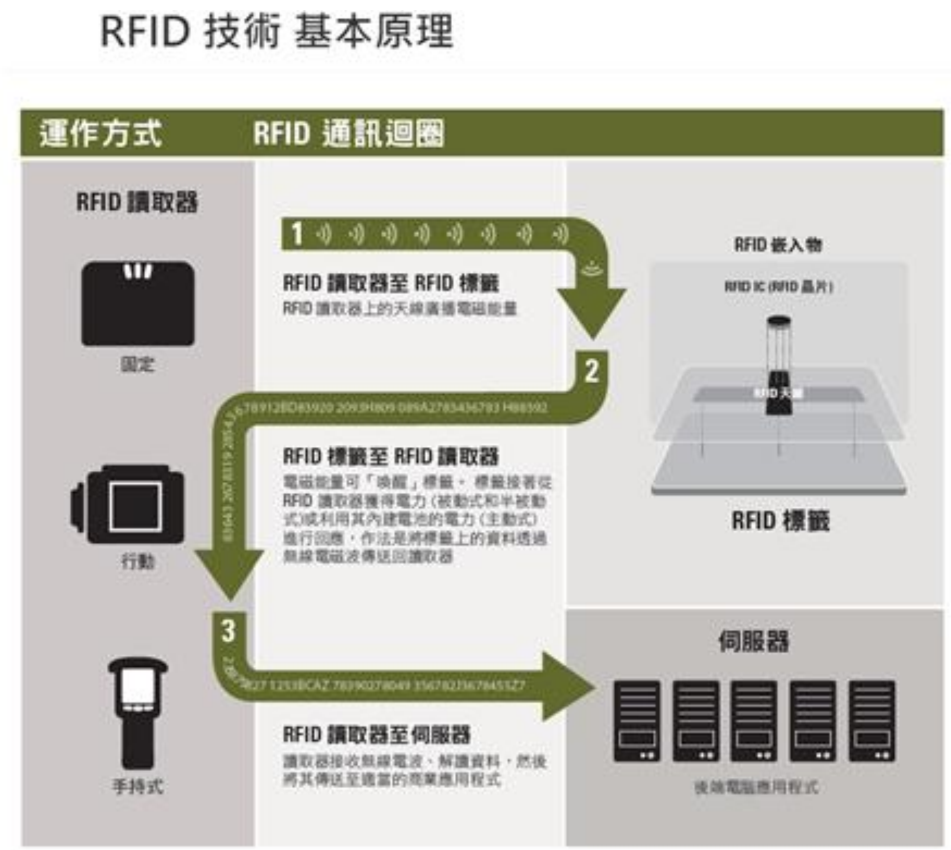
2. Antenna Applications

2.1. RFID :

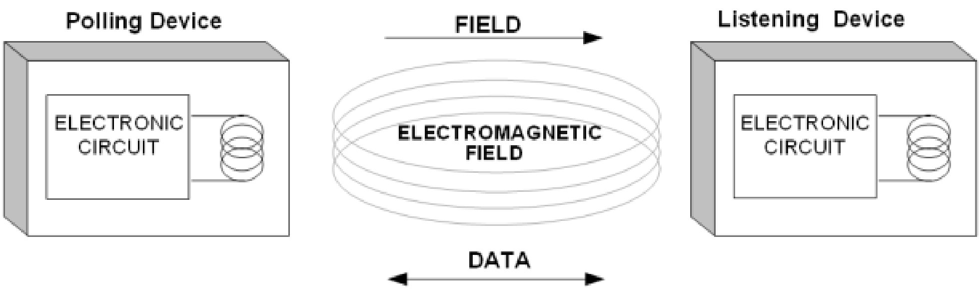
RFID stands for "Radio Frequency Identification," which in Chinese is called 無線射頻識別系統. It is typically a system composed of a reader and an RFID tag. Its operating principle is that the reader emits radio waves to activate RFID tags within its sensing range. Through electromagnetic induction, current is generated to power the chip on the RFID tag, which then emits electromagnetic waves in response to the reader. Based on the source of operating power, RFID tags can be classified into active and passive types. A passive tag has no built-in battery; all the required current is generated through electromagnetic induction from the radio waves emitted by the reader, so it only responds passively when receiving a signal from the reader. An active tag has a built-in battery, enabling it to actively transmit signals for the reader to detect, and its transmission range is relatively wider than that of a passive tag。



The ETC toll collection system used on highways is actually an application of RFID technology based on electromagnetic waves. Its principle is that the sensor mounted on the gantry communicates with the E-tag installed on the vehicle via electromagnetic waves. After calculating the distance traveled, the system then determines the toll fee。

2.2. NFC :

NFC stands for Near Field Communication, a short-range communication technology. NFC evolved from a form of "contactless" Radio Frequency Identification (RFID) and interconnection technology, providing an extremely convenient communication method for all consumer electronic products. Unlike RFID, NFC features bidirectional connection and identification. It operates in the 13.56 MHz frequency range with an effective range of about 10 centimeters。



Nowadays, nearly everyone in the Greater Taipei area has an EasyCard. Want to pay for transportation? Simply hold the EasyCard close to a designated device and "tap" it to complete the payment. This technology, which enables information exchange only at very short distances and fixed positions, is achieved through the precise coordination of a reader transmitting electromagnetic waves and a specially designed antenna embedded in the card. A similar model is also used in the increasingly popular "electronic wallet" systems。

2.3. GPS Antenna Applications (Navigation)

a. Receiving antenna (GPS Antenna ex:YIC ATPG1590R1540A)

The receiving frequencies are in the L1 and L2 bands at 1575.42 MHz and 1227.60 MHz。 These antennas are equipped with Differential GPS (DGPS) reception capability, allowing them to receive differential signals for more precise positioning corrections。

Differential Global Positioning System (DGPS): A technology used in the Global Positioning System to improve civilian positioning accuracy. The concept involves equipping a GPS receiver at a precisely surveyed location to serve as a reference station, and comparing the user’s GPS positioning results with the reference station’s coordinates to correct the GPS position solution, thereby improving the positioning accuracy for users within the local area。

b. Receiving signal processor (Engine Board ex: YIC51009EBGG-33)

The receiving signal processor mainly consists of a microprocessor, digital-to-analog signal conversion circuits, input/output interface control circuits, memory, and related algorithms. A receiving signal processor can typically receive and process signals from at least 8 to 12 satellites simultaneously。

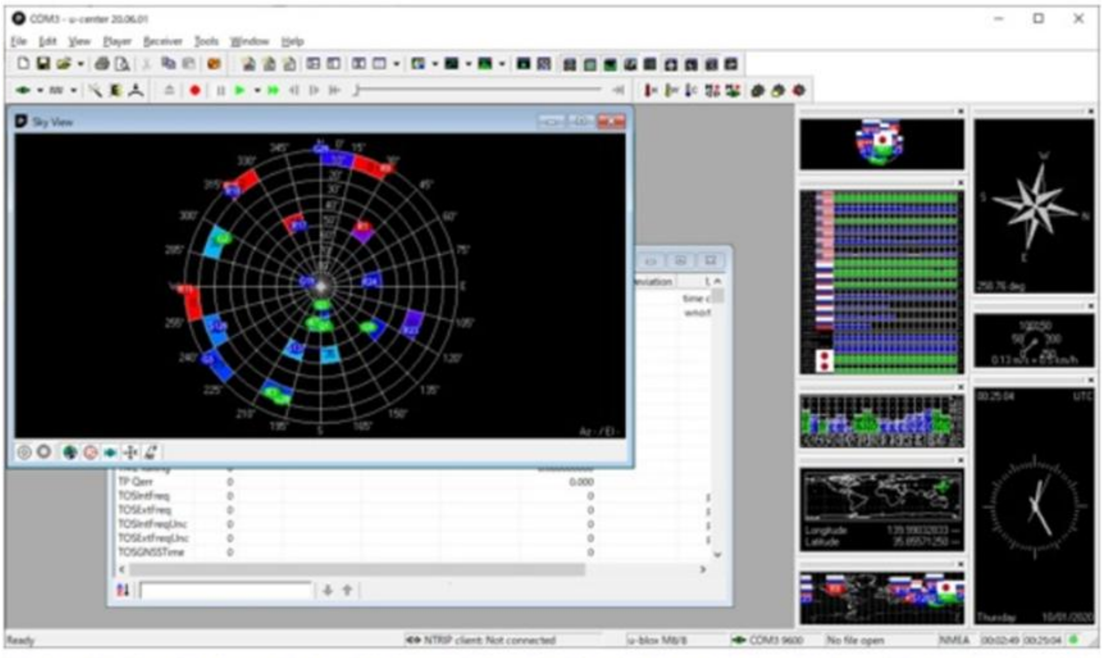
YIC GT-505GGBL5-DR

The antenna has a built-in receiving module, with a magnet on the back and a 1.5-meter cable, allowing you to attach it to a car or a window。

You can simply connect it to a computer via UART to use it。

NMEA0183，Power supply: DC 3V to 5.5V。

MTK GNSS receiver serial connection diagram



"Power GPS" can be downloaded for free from the website (and "U-center" can be downloaded for free from the U-blox website), so you only need to connect the GNSS receiver to start displaying。

However, the content displayed by this tool is more technical and requires basic knowledge of GNSS。

Since the output is in text (NMEA 0183 format), you can simply connect Tera Term to display the received information。

This output uses a universal format, so you can export it as a log file and map it onto a map。

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It is said that this receiver has an error of up to 2 meters, but even when the receiver is placed in a fixed position, the error can be as much as about 5 meters, similar to that of a map。

Car navigation systems use road information from maps to correct the position, so if the raw data has this level of accuracy, it may be even better than a car navigation system。

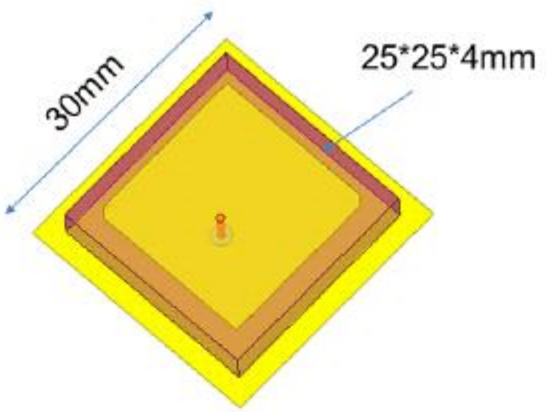
2.4. Ceramic Patch Antenna

The ground plane, where the antenna sits on the PCB, its facing direction, and what’ s around it all affect how well a ceramic patch antenna works. To get the most out of it, it’ s a good idea to have the manufacturer review your design in detail。

2.4.1 Ground Plane

The dimensions of the ground plane can influence characteristics such as the center frequency and gain of a ceramic patch antenna。

The example below shows a ceramic patch antenna mounted on a 30 mm × 30 mm ground plane, with a center frequency of 1575.42 MHz。

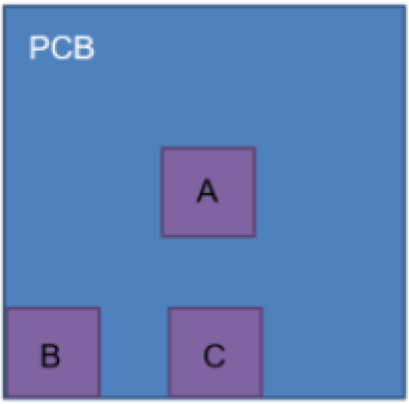


Ceramic Patch Antenna on 30*30 mm Ground Plane

2.4.2 Antenna Layout on PCB

The placement of the antenna can impact characteristics such as the VSWR and gain of a ceramic patch antenna.

Below are examples of common placement options (A: center of PCB, B: PCB corner, C: middle of PCB edge).



Different Antenna Positions (A, B, C)

For certain antennas, the best VSWR and gain are achieved when placed in position A However, other antennas may perform optimally in position B or C During product design, it is advisable to consult the antenna manufacturer for evaluation and simulation to determine the most suitable placement。

2.4.3 Antenna Direction and Environmental Factors

The radiation performance of a ceramic patch antenna is influenced by its orientation and the surrounding environment, such as nearby metal objects. It is recommended to follow the guidelines below during the design process。

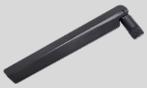
- Ensure the antenna is oriented toward the sky. If the antenna is tilted, in some cases, even with strong satellite acquisition and high C/N_0, the module's positioning accuracy may degrade due to multipath effects。
- Keep a minimum clearance of 10 mm between the patch antenna and any nearby tall metal components to avoid negatively affecting antenna performance。
- The device enclosure should be constructed from non-metallic materials, especially around the antenna area. A minimum clearance of 3 mm should be maintained between the antenna and the enclosure。

2.4.4 Feed Point of a Ceramic Patch Antenna

Ceramic patch antennas are commonly available in three feed configurations: single feed, dual feed, and quadruple feed。

- Single-feed ceramic antennas are typically used for single-band applications and have only one feed pin。
- Dual-feed ceramic antennas are commonly used for dual-band operation, with one feed pin connected to the high-frequency section and the other to the low-frequency section。

3. YIC Antenna:

GPS/GNSS 	MiMo 	5G 	4G LTE 	3G / GSM 
ATGGBL54138M-SMA-3	ATGGLTE80014M-CD	AT5G-42863-10.0WS	ATLTE-13190-2.0BTC	AT3G-10115-2.0WT
ATGGBL24138M-SMA-3	ATGLTE9030-2.5BM	AT5G-19170-3.0BT	ATLTE-27222-2.0BT	AT3G-13190-2.0BTC
ATGG46015-BP	ATGLTE7220-3.0BM	AT5G-20145-3.0BT	ATLTE-25167-2.0BT	AT3G-19171-2.0BT
ATGGB4336	ATGLTEAF69182-3.5BP		ATLTE-25221-2.0BT	AT3G-25221-2.0BT
ATGG4336	ATGGLTEW80014-CD		ATLTE-13196-3.0BT	AT3G-13196-3.0BT
ATIGGBL52580-100	ATGGLTEW50048-2.0BP		ATLTE-13172-5.0BT	AT3G-13196-3.0BT
ATIGGBL22580-100	ATGGLTEW84018-2.0BP		ATLTE-13240-5.0BT	AT3G-13172-5.0BT
ATIGGBL2L52580-100	ATG3G35095-2.5BA		ATLTE-16192-5.0WT	AT3G-13240-5.0BT
ATIGG2540	ATG3G36096-2.0BM		ATLTE-22229-5.0BT	AT3G-22116-3.0BA
ATIGG1840	ATG3G68055-2.0BP		ATLTE-60214-2.0BM	AT3G-60214-2.0BM
ATIGGB2540	ATG3G7214-2.0BM		ATLTE-83170-2.0BM	AT3G-83170-2.0BM
ATIGB25	ATG3G7520-3.0BM		ATLTE-83170-2.0WM	AT3G-83170-2.0WM
ATIGB18	ATG3G94133-2.0WP		ATLTE-46015-2.5BP	AT3G-30095-2.5BM
ATPGGBL5R2580A	ATGG3GW84018-2.0BP		TLTE-12105-3.0BTC	AT3G-45311-5.0BM
ATPG1590R3560A			ATLTE-19171-2.0BT	AT3G-46015-2.5BP
ATPGD1590R3540A			ATLTE-30300-3.0BM	AT3G-12105-3.0BTC
ATPGD1590R2540A			ATILTE	AT3G-30300-3.0BM
ATPG1590R2540A			ATIFLTE	ATI3G
ATPGGBR2540A			ATIFLTE-3217	ATIF3G
ATPG1568R3560A			ATIFLTE-5717-80	ATIGSM
ATPG1568R2540A				ATIFGSM
ATIFGGBL5-4020				

Wi-Fi、Bluetooth 	DAB 	ISM / RFID 	SDARS (SIRIUS/XM Radio) 
ATW6-19170-3.0BT	ATDAB-34280-0BM	AT433M-08060-1.5BT	AT2332.5M-4336-30BTB
AT2458G-255255-10WP	ATDABUF-20113-15.0BM	AT433M-29172-2.0BM	
AT2.4G-09082-2.0BTH		AT433M-30140-2.0BM	
AT2.4G-10109-2.0WT		AT433M-29145-2.5BM	
AT2.4G-13136-3.0WT		ATP868R2540A	
AT2.4G-13190-5.0BTC		ATI868M	
AT2.4G-13191-5.0BTC			
AT2.4G-13195-5.0BT			
AT2.4G-13210-5.0BT			
AT2.4G-13295-7.0WT			
AT2.4G-13394-9.0BT			
AT2.4G-28110-0.6BM			
AT5.8G-13295-7.0WT			
AT2458G-10087-2.0BT			
AT2458G-12157-2.0BT			
AT2458G-60218-2.0BM			
ATI2.4G2540-1.37-150			
TI2.4G2540-MMCX			
ATI2458G-4717-55			
ATI2.4G			
ATI5.8G			
ATI2458G			
ATIF2.4G			
ATIF5.8G			
ATIF2458G-3010			