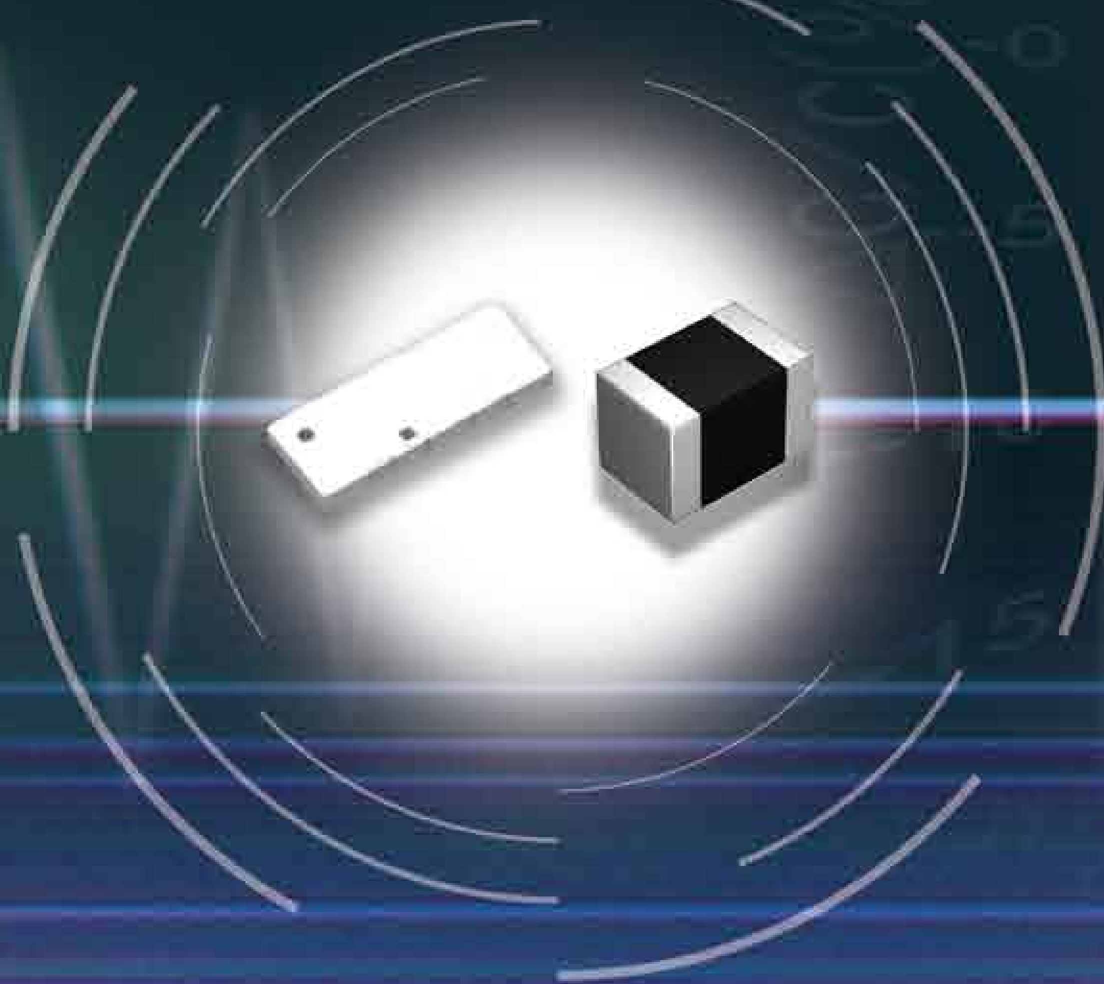
Taiyo Yuden's Chip-Antenna Solutions!

The distress of hand held device designing…

◆How can antennas be designed to use resource effectively!!



Bluetooth® and many other wireless functions have been embedded these days in not only cellular phones but also digital device, such as smart phones, PCs, game devices, audio players, and digital still cameras.

Naturally, many problems related to electronic design can be expected in the near future, including crowding due to expanding number of antennas resulting from more and more wireless applications for these devices.

In the past, most hand held device manufactures designed antennas on their own.

But the number of manufacturers adopting chip antennas for Bluetooth, Wireless-LAN, and GPS has been increasing recently.

In this section, we will focus on problems pertaining to cost and design resources for hand held device manufacturers, and demands for chip antennas.

*Bluetooth® is a registered trade name of Bluetooth SIG Inc.

Pattern and Plated Antennas

Most hand held device manufacturers design pattern antennas, which are made on a circuit board, or plated antennas, which use metal plates and inexpensive materials.

Pattern antennas aim to reduce costs by the design of a meander line and turn-up on circuit boards.

Plated antennas, by contrast, aim to optimize the use of space by conformation [e.g., creation of an antenna in between the case and the substrate].

Nevertheless, the required case size is equivalent to $\lambda/4$(about 30㎜ in the 2.4 GHz band) of the pattern lengths, and the substrate material is limited with respect to miniaturization due to a low dielectric constant.

Furthermore, space is insufficient for retaining characteristics on design of hand held devices.

Effective use of Design Resources

As you may have realized, if a hand held device manufacturer designs antennas on its own, it must adjust its design resource antennas for development [so-called" matching"], conduct evaluations in an anechoic chamber, and manage appropriate patterns and materials for mass production.

If invisible costs attributable to antenna design were included, the total cost would be much bigger.

If we were to list all design costs attributable to antenna design, they would appear as shown in Table 1.

For example, if the number of shipped hand held devices were to total 500,000 sets, the antenna cost per set would be 5 cents.

The above costs are just attributable to antenna design expenditures.

In case of plated antennas, additional expenditures will be required for materials, metallic molds, and material management. Of course, hand mounting is more expensive than machine mounting, and hidden costs must be considered because it has also problems resulting from quality assurance due to mounting variations.

More importantly, costs for plated antennas rise due to the need for hand mounting and embedded costs are very high. Of course, hand mounting has problems resulting from quality assurance due to mounting variations.

Material and design costs per plated antenna, for example, will therefore be at least about 10 to 12 cents, despite the per -antenna cost of materials being about 5cents.

If mounting management and hidden costs are considered, the total cost will be around 15 to 17 cents per plated antenna.

In some ways, the costs are minimal, According to a technical executive of cellular phone manufacturers, "It's difficult for us to order valued antenna design engineers to design antenna for a single application. It's more valuable to ask them to design for a new application or a cellular-band antenna." This may be true, so, it is a big problem for cellular phone manufacturers now.

Design an antenna on a hand held device, manufacturers have to consider not only the cost of components, but also miniaturization, characteristics, and design resources (design, adjustment, evaluation, management). Especially with respect to design resources, designing resources is a tough problem, and difficult factors such as calculating costs exist.

In the future, more antennas for varieties of applications will be embedded in cellular phones so many antennas will likely exist in one single cellular phone.

Of course, there is a limitation on the designing of antennas for each application internally.

As a hand held device itself, it is important to allocate design resources for arranging the antenna and handling each merit.

This is particularly true for cellular phone manufacturers wishing to allocate design resources for antenna development of a new application, and next-generation cellular phones.

Chart 1. Trial balance for antenna development costs

Total Antenna development cost is approximately $30,000 !		
Antenna Design Fees		Approximately $8,250 (Design/Development: 150hrs)
Antenna Matching	Labor costs	Approximately $830 (Trial 5 times [at least] x 3hrs [per a trail] x labor cost)
	Rental fees for anechoic chamber	Approximately $19,500 (Trial 5 times [at least] x $3,000@rental fees)
Antenna Evaluations	Labor costs	Approximately $1,380 (Evaluated 5 times [at least] x 5hrs [per a trail] x labor cost)

+

In case of designing plated antenna, there are additional costs in die, materials, and management expense

*This trial balance is based on our research of times and costs.
We set the labor cost per an engineer as $50/hrs considering all costs at company including benefit programs.

Features of Chip Antennas

One of a chip antenna's main features is miniaturization.

Chip antennas can be miniaturized by dielectric constant (ε-r) of ceramics, and minimize just $1/\sqrt{\varepsilon}$-r against the original required wavelength.

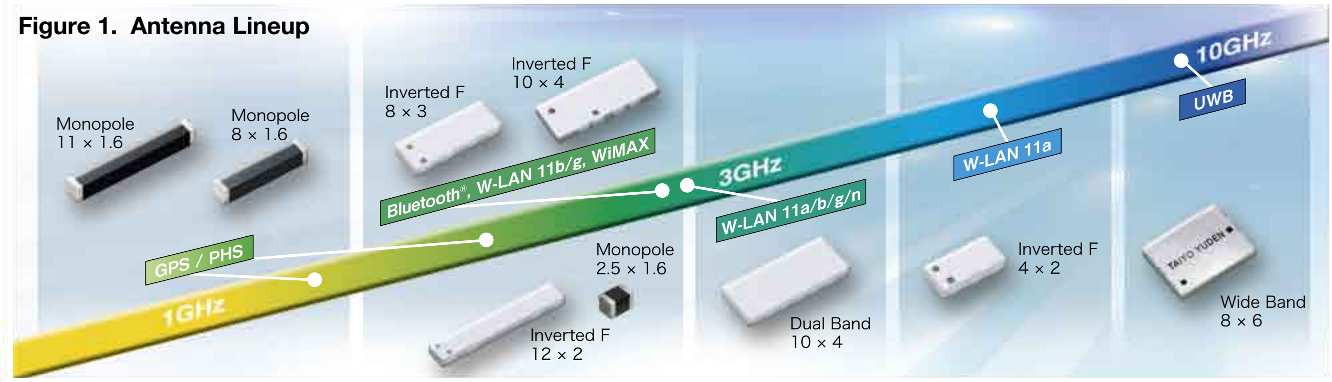
Thus, in theory, the higher the dielectric constant of chip antenna is, the smaller the antenna size.

As a matter of fact, the wavelength reduction effect is limited due to the dielectric material loss.

At Taiyo Yuden, it is common to use materials having a dielectric constant of around 8 to 30.

By doing so, although the length of $\lambda/4$ in the 2.4GHz band is 30 ㎜, Taiyo Yuden is able to miniaturize chip antennas approximately 1/10th to 1/3 rd (2.5㎜ to 10㎜) thanks to the miniaturization

Figure 1. Antenna Lineup



effect of the electrode arrangement and the wavelength reduction effect of the dielectric constant. The applicable frequency band of ceramic chip antennas is in the 1.5GHz to 10 GHz band used by GPS, W-LAN, WiMax, and UWB. This GHz band is the optimal for balancing the size and characteristics of chip antennas (see **Figure 1**)
We think the market size for ceramic chip antennas will grow from now on.
Moreover, chip antennas are suitable for the trend of antenna standardization.
The significance of this standardization is the unification of antenna components as much as possible, and standardization of antenna design for many different terminals.
In case of antennas, most design engineers think antenna standardization is difficult because different characteristics are required for each terminal, and also required for high customization in design.
Even so, the setting of specific conditions for surrounding environments and embedding methods is leading to standardization gradually. Again, design trends and antenna standardization by terminal manufacturers are increasing due to the high stability of chip antennas as quality elements.

Chip antenna trends

As mentioned above, the needs for chip antennas will be increasing due to antenna design requirements, which are reduction of total costs and effective utilization of design resources, and those of the chip antenna's features, are miniaturization and standardization.

Taiyo Yuden's Chip-Antenna Solutions

Given these considerations, reducing antenna design resources, Taiyo Yuden offers the following solutions: ① Fully-equipped state of the art anechoic chambers. ② Chip Antenna lineup based on high production technology
③ High level of technical support*
Like the above three different solutions, Taiyo Yuden has world-class technologies in the antenna industry. Taiyo Yuden has two different kinds of anechoic chambers for antenna development, evaluation, and support: The first is an installed system by which 3 dimensional antenna radiation patterns and antenna efficiency can be measured instantly.
Another is common hexahedron anechoic chamber where high frequency up to 110 GHz can be accurately measured (see **Photo 1**).

＊With respect to all of our anechoic chambers, Taiyo Yuden owns these systems for developing Taiyo Yuden's antennas, and uses them to provide technical support for customers who use Taiyo Yuden's antennas. We therefore currently, do not provide a service for leasing these systems only. Doing so, we can offer total service for satisfying our customers.

In addition, one reason why Taiyo Yuden satisfies wireless communication handheld device manufacturers is its finely textured technical support. From the point of view of an antenna manufacturer, Taiyo Yuden always has many technical know-how for supporting customers to design an antenna, what the right space for embedding an antenna is , matching technologies for embedded on an actual equipment, characteristics measurements, measurement technologies by using phantoms (homunculus that sets the same dielectric constant level of the human body)(see **Photo 2**), and accumulated data for an antenna standardization. We have offered various proposal from them, as customers request.(see **Photo 3**).
Offering top-to-bottom technical support for our customers who have insufficient antenna measurement facilities and lack antenna development experience, Taiyo Yuden has a favorable reception

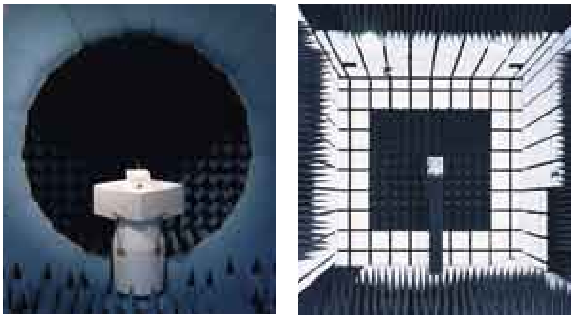


Photo 1. Stargate System, Anechoic Chamber

Photo 2. Human Phantom

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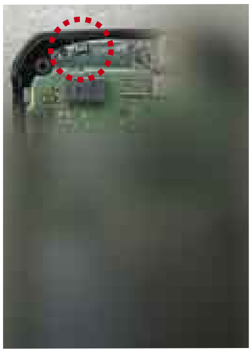
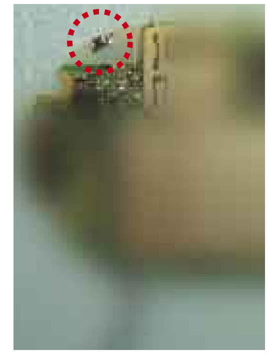
Picture 3. Proposal for antenna mounting position -the practical proposal by using actual device





from many customers.Nowadays, requests for technical support are changing day by day, so we would like to support such requests.

Taiyo Yuden's antennas are created based on our originally developed ceramic materials.

Taiyo Yuden's antenna lineup can roughly be divided into two kinds:

One is a helical-type antenna, which is Taiyo Yuden's original wire-wound structured type. And another is a multilayer-type antenna, which was created based on multi-layer ceramic technology.

Adding to 1.5GHz band helical antenna for GPS(11 ㎜ × 1.6㎜ × 1.6㎜：AF116M157502), Taiyo Yuden started mass-production of new items for cellular phones(8 ㎜ × 1.6㎜ × 1.6㎜: AF816M157502) in autumn of 2007.

Notably, the helical antennas for 2.4GHz band Bluetooth and W-LAN(2.5㎜ × 1.6㎜ × 1.6㎜: AF216M245001)comprise the world's smallest level antennas and are used for many applications such as cellular phones and portable audio players.

Taiyo Yuden provides antennas relatively difficult to design for antenna manufacturer such as reverse F antennas, dual-band antennas, and wide-band antennas by using a multilayer structure.

In particular, multilayer antennas for the 2.4 GHz band(10 ㎜ × 4 ㎜ × 1 ㎜: AH104F2450S1) are long-seller products as high-performance reverse F. Moreover, we released the new antenna product 8㎜ × 6㎜ × 1㎜(AH086M555003) applicable for wide band as WiMAX(3.5GHz) and UWB.

From now on, adding to the above new items, we are developing ultra-small-antennas.

Meanwhile, we will release 0.5-㎜-thick multi-layer antennas for the 2.5GHz band in the near future.

Future trends and Taiyo Yuden's development approaches

For the future, antennas are going to be needed for each wireless communication system embedded in handheld device. Most notably, cellular phones will be embedded with many wireless communication systems such as cellular phones bands, digital terrestrial devices, Bluetooth®, GPS, RFID, W-LAN, and WiMAX, so there are two important points to consider: How can such characteristics be output and where should an engineer embed the antennas within the devices?

At the same time, semiconductors are also being developed to become to include many different functions, as combination IC.

For these ICs, antenna manufacturers are also rapidly developing antennas combining many resonations (dual-band, triple-band), developing wide-band antennas to cover from a certain frequency to another certain frequency at once, and developing antennas for MIMOs, which can transmit and receive at the same time, using multiple antennas.

At Taiyo Yuden, we are also developing these combined and wide -band antennas, and are developing antennas by using new materials or many different approaches such as active antennas, which include electronic circuits.

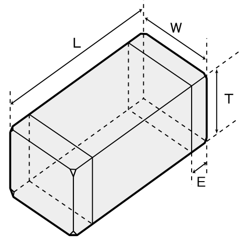
Also Taiyo Yuden, as a part of our technical support, will fulfill design guidelines and characteristics data for antenna installation in order to satisfy our customers and will propose antenna solutions for solving problems related to antenna design.

Table 2.

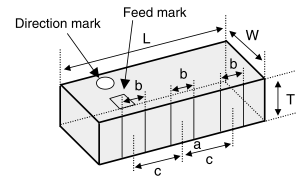
ANTENNA	Frequency (MHz)	Item	Type	Dimensions (mm)
Bluetooth® &WiFi (802.11b/g) WiMAX	2400 ～ 2600	Inverted-F	AH104F2450S1	10×4.0×1.0
			AH083F245001	8×3.0×1.0
			AH122F245001	12×2.0×1.0
		Monopole	AF216M245001	2.5×1.6×1.6
WiFi (802.11a/b/g)	2.4/5GHz Dual	Monopole	AH104N2450D1	10×4.0×1.0
		Monopole	AH104N2450D2	10×4.0×1.0
GPS	1575	Monopole	AF116M157502	11×1.6×1.6
			AF816M157502	8×1.6×1.6
WiMAX/UWB	3.1 ～ 10.6	Monopole	AH086M555003	8×6×1.0

◆ EXTERNAL DIMENSIONS ◆

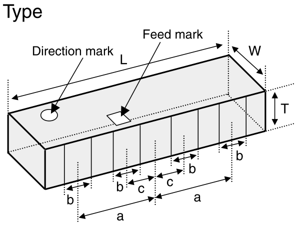
216M Type, 116M Type



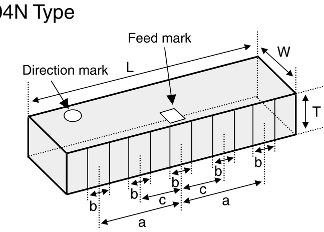
042F Type



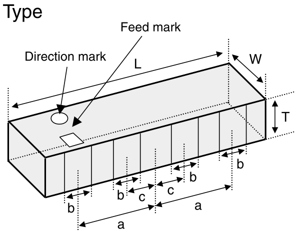
104F Type



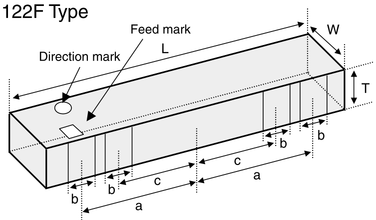
104N Type



083F Type



122F Type



Item	L	W	T	E	a	b	c
216M	2.5 ± 0.2	1.6 ± 0.2	1.6 ± 0.2	0.5 ± 0.3	–	–	–
116M	11.0 ± 0.2	1.6 ± 0.2	1.6 ± 0.2	0.5 ± 0.3	–	–	–
104F	10 ± 0.30	4 ± 0.30	1 ± 0.30	–	2.5 ± 0.30	1 ± 0.30	1 ± 0.30
083F	8 ± 0.30	3 ± 0.30	1 ± 0.30	–	3.1 ± 0.30	1 ± 0.30	1.15 ± 0.30
122F	12 ± 0.30	2 ± 0.30	0.95 ± 0.30	–	5.1 ± 0.30	1 ± 0.30	3.1 ± 0.30
042F	4 ± 0.30	2 ± 0.20	0.8 ± 0.20	–	0 ± 0.30	0.6 ± 0.30	1.3 ± 0.30
104N	10 ± 0.30	4 ± 0.30	1 ± 0.30	–	3 ± 0.30	0.8 ± 0.30	1.5 ± 0.30

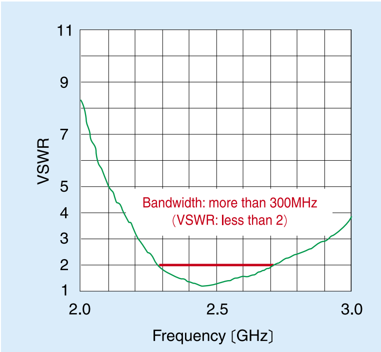
Unit：mm

◆ Part Numbers · Electrical Characteristics · Typical Characteristics ◆

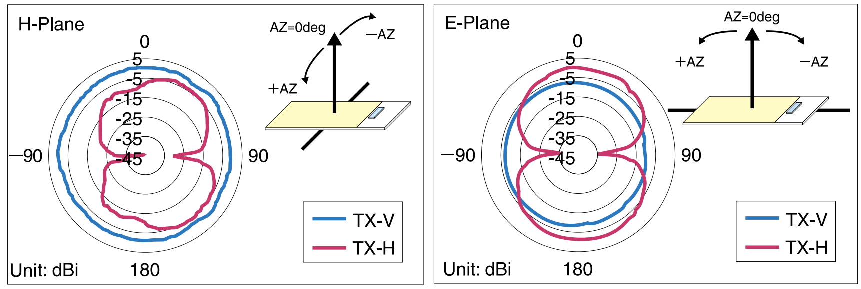
Typical Characteristics on Taiyo Yuden evaluation board

Item	EHS (Environmental Hazardous Substances)	Center Frequency (MHz)	Peak Gain	Bandwidth
216M	RoHS	2450 (TYP)	+1dBi	300MHz min (VSWR=2 max)
116M	RoHS	1575 (TYP)	+1dBi	120MHz min (VSWR=2 max)
104F Series	RoHS	2250 (TYP)	+2dBi Example of representative	300MHz min (VSWR=2 max) Example of representative
		2350 (TYP)		
		2450 (TYP)		
		2550 (TYP)		
		2650 (TYP)		
083F Series	RoHS	2310 (TYP)	+2dBi Example of representative	145MHz min (VSWR=3 max) Example of representative
		2380 (TYP)		
		2450 (TYP)		
		2520 (TYP)		
		2590 (TYP)		
122F Series	RoHS	2290 (TYP)	+1dBi Example of representative	200MHz min (VSWR=3 max) Example of representative
		2370 (TYP)		
		2450 (TYP)		
		2520 (TYP)		
		2600 (TYP)		
042F	RoHS	5250 (TYP)	+1dBi	240MHz min (VSWR=2 max)
104N	RoHS	2450 (TYP)	0dBi	530MHz min (VSWR=2 max)
		5400 (TYP)	−1dBi	1.3GHz min (VSWR=2 max)

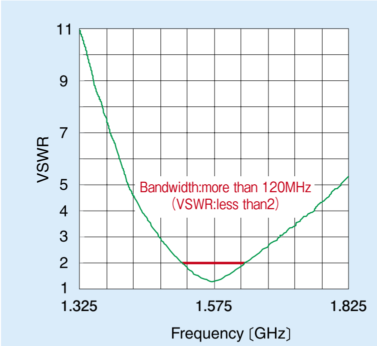
◆ Part Numbers · Electrical Characteristics · Typical Characteristics ◆



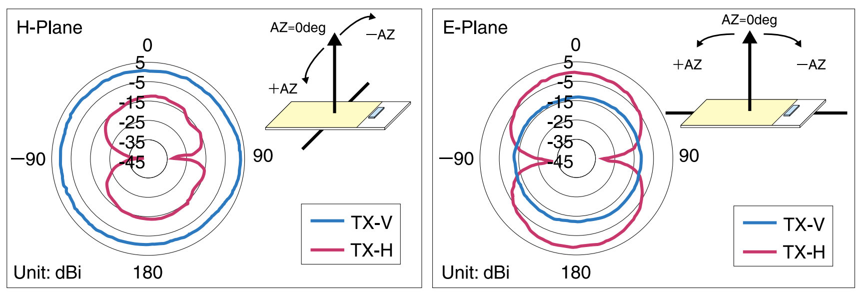
Typical characteristics of VSWR (216M)



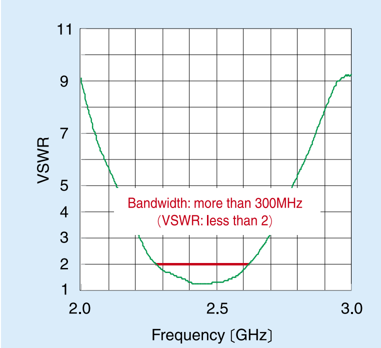
Typical characteristics of radiation pattern (216M @2.45GHz)



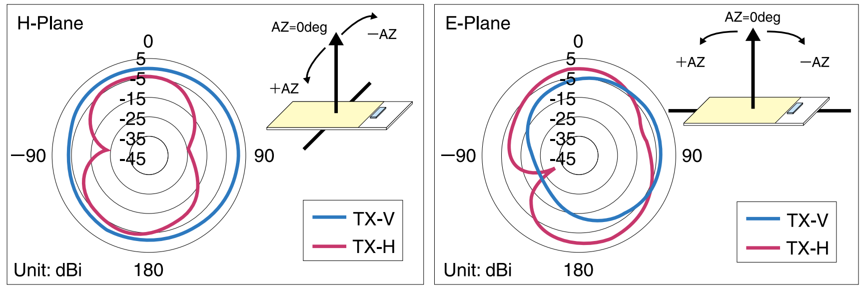
Typical characteristics of VSWR (116M)



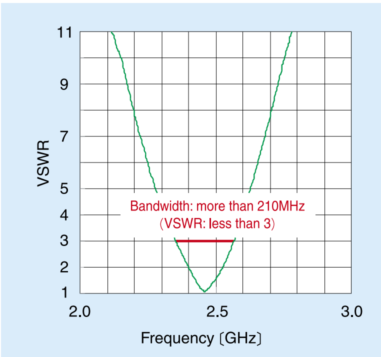
Typical characteristics of radiation pattern (116M @1.575GHz)



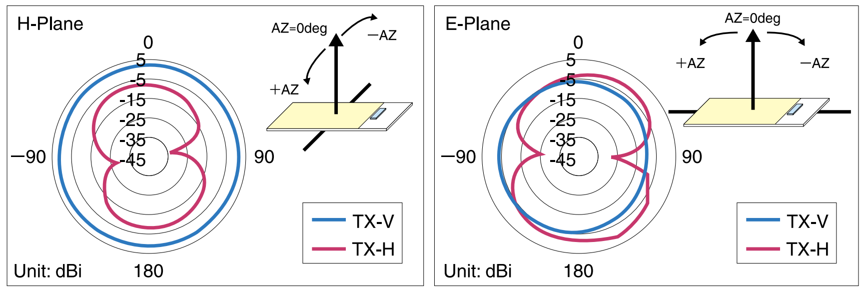
Typical characteristics of VSWR (104F series)



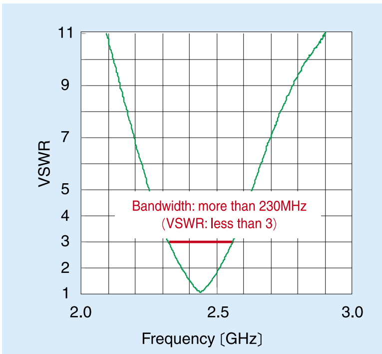
Typical characteristics of radiation pattern (104F series @2.45GHz)



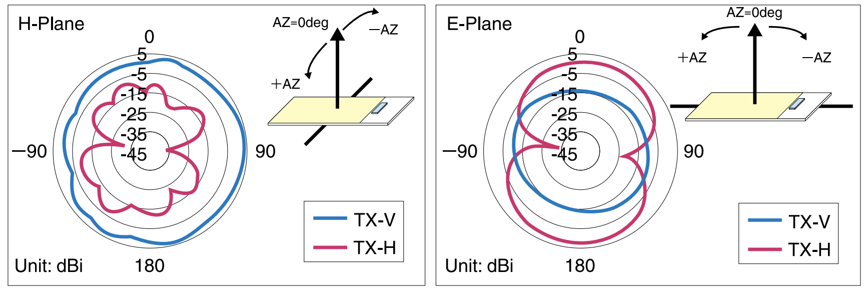
Typical characteristics of VSWR (083F series)



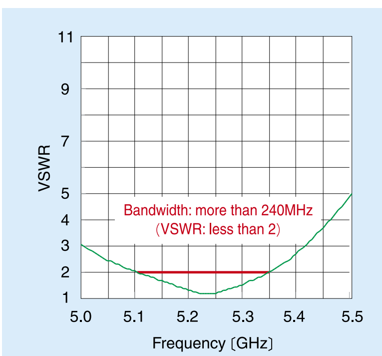
Typical characteristics of radiation pattern (083F series @2.45GHz)



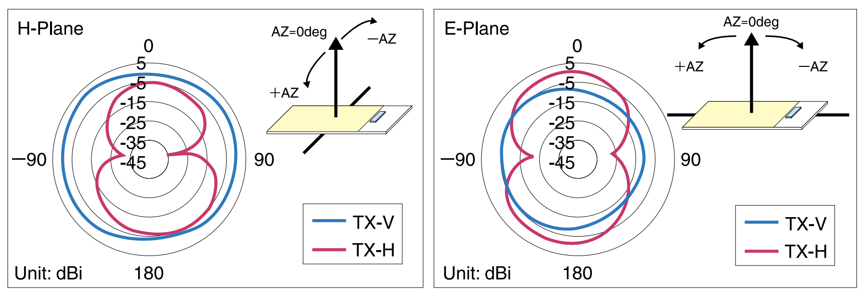
Typical characteristics of VSWR (122F series)



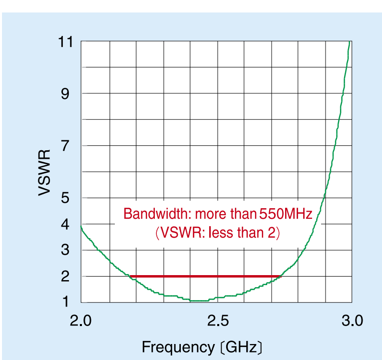
Typical characteristics of radiation pattern (122F series @2.45GHz)



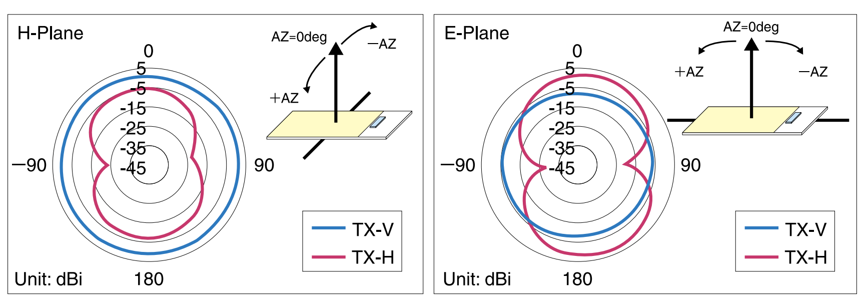
Typical characteristics of VSWR (042F)



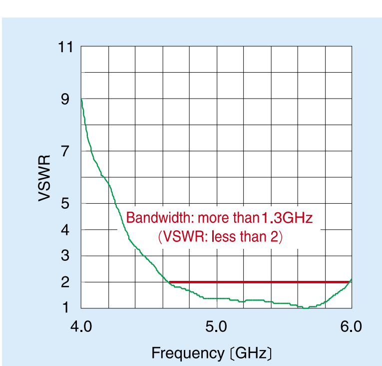
Typical characteristics of radiation pattern (042F @5.25GHz)



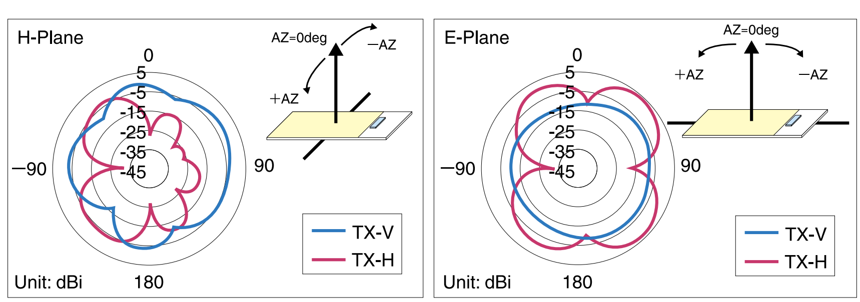
Typical characteristics of VSWR (104N 2GHz band)



Typical characteristics of radiation pattern (104N @2.45GHz)



Typical characteristics of VSWR (104N 5GHz band)



Typical characteristics of radiation pattern (104N @5.4GHz)