ICOM

IC-905

Development Philosophy and Commitment

~ Profile ~

Let’s move up, into the world of the VHF/UHF bands and beyond to the SHF band.

The SHF band is defined by the International Telecommunication Union (ITU) as the frequency band between 3 GHz and 30 GHz. In amateur radio, the HF band (3 MHz ~ 30 MHz), VHF band (30 MHz ~ 300 MHz), and UHF band (300 MHz ~ 3 GHz) are commonly used, but in the UHF band, operation up to the 430 MHz band has become mainstream. However, there are also many bands open to amateur radio in the SHF band, the frequency band above the UHF band.

Many amateur radio operators have a negative image of the SHF band, such as, “This band can be operated by a very limited number of amateur radio operators,” “It may be operated at the study level,” “It seems difficult to handle the frequency,” and “The radio propagation does not go that far away.” However, SHF-band communications are surprisingly close at hand. Wireless LAN (Free Wi-Fi®) available at commercial facilities and cafes, and what is called “5G” used in smartphones are also communications using the SHF band. Smartphones and “5G” are naturally commercial radio communications, but despite their low power output, communication with base stations is never interrupted. Note that “5G” does not mean the 5 GHz band, but represents the 5th Generation mobile communication system using the 3.7 GHz band (3.6 ~ 4.2 GHz), 4.5 GHz band (4.4 ~ 4.9 GHz) and 28 GHz band (27.0 ~ 29.5 GHz).

Icom, an amateur radio manufacturer, has also been conducting research and basic studies on the SHF band since its inception. The IC-905 is the result.

There are misconceptions about the SHF band. The SHF band has unlimited possibilities, and you should be able to enjoy the world of this band just as much as any other amateur band! The following is an explanation of this world of the SHF band and the IC-905’s designers’ commitment to it.

Trademarks

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- PART 1 -

Design Background 01

Design Philosophy

In 2020, we commercialized the IC-SAT100, Icom's first radio that communicates through satellites, although it is a radio for professional use. This radio used the SHF band, and its development triggered a call from within the company for the creation of something fun and exciting that would pave the way to the future of amateur radio. We focused our attention on the SHF band, an area that had not been explored by many amateur radio manufacturers, including Icom.

Figure 01-1. IC-SAT100 SATELLITE PTT

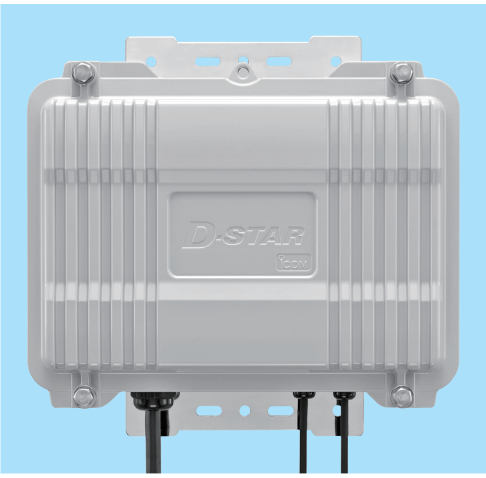

Figure 01-2. ID-RP2L 10 GHz Assist Repeater

As a product development in the SHF band, Icom commercialized the D-STAR® 10 GHz band assist repeater about 20 years ago. Since this is a repeater, it is not a product that amateur radio operators use by holding it directly in their hands.

This time, we have commercialized an SHF transceiver that can be directly operated by amateur radio operators by utilizing the RF technology in the SHF band. We worked on the design with the hope of contributing to the revitalization of the SHF band in amateur radio, even if only in a small way. After a study of the radio propagation characteristics of the SHF band and the operability of the radio, the IC-905, which will open the way to the future of amateur radio, was born. This is in line with Icom's philosophy of creating a variety of communication devices.

Design Background

Figure 01-3. Marine radar antenna

In the past, the SHF band was a frequency band used for radar. Then, in 2001, ETC (Electronic Toll Collection system) services using the SHF band were launched in Japan, and its use in wireless data communications such as Wi-Fi® has increased with the spread of the Internet. In addition, the transition from the UHF band to the SHF band is accelerating in familiar wireless communications, as smartphones are also expanding from LTE to 5G. With the spread and increase in demand for these consumer products, the components used are becoming increasingly IC and modular, contributing to the miniaturization of the products themselves.

While data communication using the SHF band is dominant in the world, radio communication that transmits and receives analog voice is now probably limited to amateur radio. The electronic components, filters, antennas, and other components used in SHF band amateur radio equipment are unknown and unimaginable, even to HF and VHF band experts, and only a few amateur radio operators enjoy building radio equipment using their knowledge and skills.

Although electronic components that can be used in the SHF band are still expensive, there are many electronic components that can be converted to amateur radio equipment. However, special techniques are needed to bring out the performance of these components, and high-performance measuring instruments compatible with the SHF band are required for design. Furthermore, mounting and assembly of electronic components also require advanced technology. For this reason, it may be a world that interests you as an amateur radio operator.

Still, there is no guarantee that designing and commercializing SHF band products will be profitable for us as a manufacturer. Nevertheless, as an amateur radio manufacturer, we believe that lowering the hurdles to communication in the SHF band and at the same time providing products that tickle the ambition, interest, and spirit of inquiry of amateur radio operators will lead to increased activity in the SHF band.

The design of this amateur radio was developed with the aim of enabling operation of as many radio types as possible with a single unit, from CW, the origin of radio communications, to ATV, which is popular in the 1.2 GHz band and above, to D-STAR®, which is becoming the standard in the VHF and UHF bands.

Figure 01-4. 10 GHz Parabolic antenna

Initial Concept

At the conceptual stage of the IC-905 development, the signal loss in coaxial cable was discussed as an issue within the team. After considering the issue from various angles, we decided to proceed with a structure in which the controller, which serves as the user interface, and the RF unit, which contains the front end, are completely separate, and the RF unit can be installed directly under the antenna. However, while installing the RF unit directly under the antenna greatly reduced the loss in coaxial cable, the method of supplying power to the RF unit presented a new challenge.

Figure 01-5. Antenna and RF unit configuration for commercial wireless LAN system

Figure 01-6. Icom PoE-compliant switch VE-SW8

Icom is also involved in the design and manufacture of network equipment. We considered applying PoE (Power over Ethernet) technology, which is used in some of this network equipment. However, since amateur radio equipment has a higher RF output than network equipment, for example, 10 W in the 1.2 GHz band and 2 W in the 2.4 GHz/5.6 GHz band, the problem of power supply capacity supplied through the cable also arose. At one time, we considered reducing the transmit output power to 1 W for all bands, but we received comments such as, “No matter how much we reduce losses, 1 W transmit output power is not attractive as a fixed station radio,” so we decided to maintain 10 W in the 1.2 GHz band and 2 W in the 2.4GHz/5.6 GHz bands without reducing transmit output power by applying PoE++ technology. The PoE++ technology is described in “Applications of PoE++ Technology”.

Even after clearing this power supply challenge, we also found a problem where the target transmission output could not be obtained in the 1.2 GHz, 2.4 GHz, and 5.6 GHz bands. Efforts to address this problem will be explained in “Selection of Devices to be Used.”

- PART 2 -

02 Design Goal

Inherited Technology

Direct Sampling Processing

Since the launch of Icom's explosively popular HF/50MHz all-mode IC-7300, the RF direct sampling method has been used, which has become the standard for Icom's all-mode equipment. The newly developed IC-905 also uses the RF direct sampling method. Like the IC-9700, the IC-905's RF direct sampling method operates in the 144 MHz and 430 MHz bands. By converting the received RF signal directly into a digital signal, complex signal processing such as mixer, IF filter, and demodulation, which were conventionally performed by analog circuits, are all processed together in the FPGA.

Figure 02-1. IC-7300 with the RF direct sampling method

Down Conversion IF Sampling Processing

RF signals in the 1.2 GHz band and above are down converted to the 351 MHz band before the IF sampling processing. In the 1.2 GHz band, local oscillation signal of the 920 MHz-band generated by the PLL/VCO is down-converted by the Active Mixer to generate a 351 MHz-band IF signal which is then IF sampled. In the 2.4 GHz and 5.6 GHz bands, the local oscillation signal of 1200 MHz and 4400 MHz generated by the PLL/VCO are down converted to a 1200 MHz IF signal by the Active Mixer, and the 351 MHz IF signal is generated by the same route and processing as in the 1.2 GHz band for IF sampling. These A/D converters, FPGAs, PLL/VCOs, and mixers are selected based on a comprehensive evaluation, including current consumption and cost, while emphasizing signal purity in terms of C/N characteristics and phase noise.

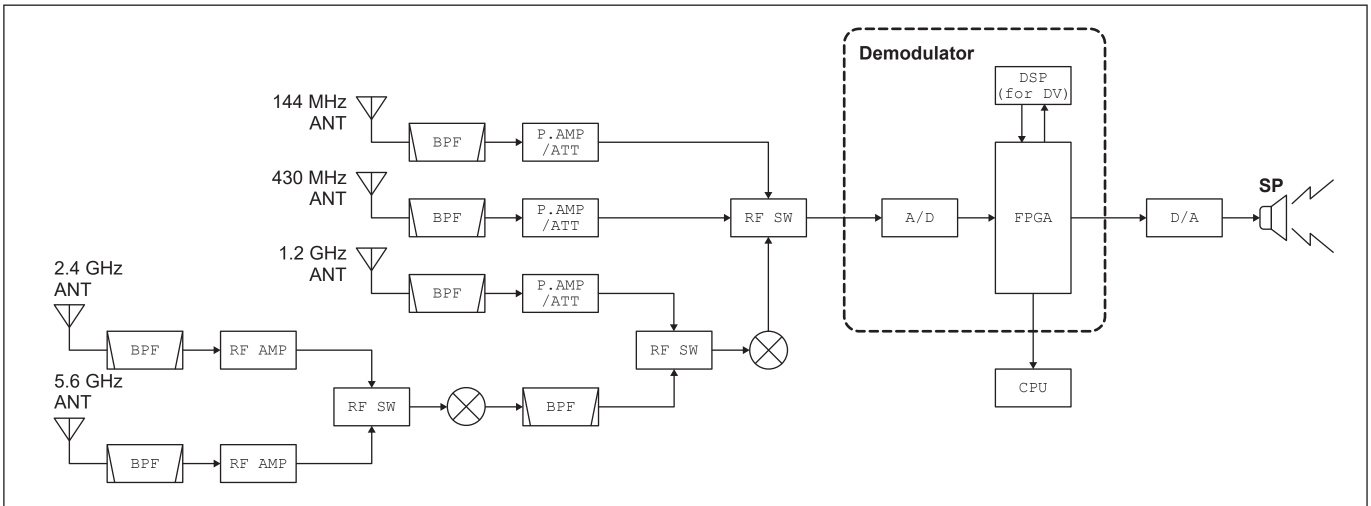

Figure 02-2. Block diagram of the IC-905 direct sampling processing

Operational Modes

Although the FM mode is the most common mode in the VHF, UHF, and SHF bands, we began designing the IC-905 as an all-mode radio because it is intended mainly for operation as a fixed station. Since the radio to be designed is a VHF and UHF band radio, we decided to cover the 1.2 GHz, 2.4 GHz, and 5.6 GHz bands, and in addition to the SSB, CW, RTTY, AM, and FM modes included in all-mode radios, we also included Icom's unique DV, DD, and ATV modes.

Figure 02-3. Mode selection screen

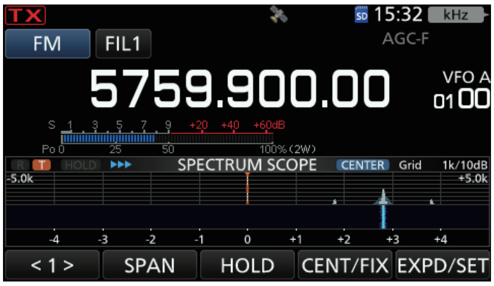

Figure 02-4. Screen showing frequency deviation of approximately 2.8 kHz

However, frequency stability is a major issue for all-mode equipment at these very high frequencies. For example, if the frequency stability is 0.5 ppm at 5700 MHz, a maximum frequency deviation of 2.85 kHz is acceptable. If the frequency is off by 0.5 ppm in the opposite direction from the other station, the maximum frequency difference will be large at 5.7 kHz. While it may be possible to communicate in the FM mode even with this frequency discrepancy, it will be very difficult to communicate in the SSB or CW modes.

In addition, the phase noise of the transmitted signal must be kept low to reduce SSB and CW adjacent frequency interference. These issues are discussed in detail in "SSB/AM Compliance" and "Transmit Signal Generation and Phase Noise."

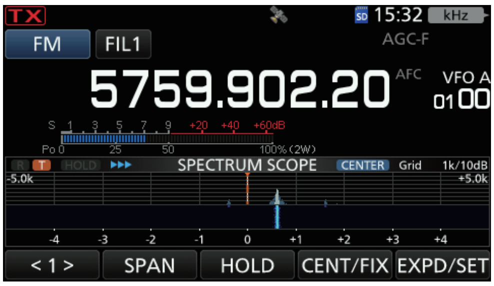

Figure 02-5. Automatically adjusts the frequency to correct any deviation with AFC

Controller and Operation System

The controller of the IC-905 is almost identical to that of the IC-705 in size and placement of dial and knobs. One difference on the front panel is the transmitter/receiver indicator of the IC-705. In the IC-705, that indicator was shared, but in the IC-905, since the battery pack cannot be attached to the rear panel as it is on the IC-705, the charging indicator which is no longer used and it is allocated to the receiver, so that the transmitter and receiver indicators are independent of each other. In addition, the IC-905 added an AFC (Automatic Frequency Control) function to the [AUTOTUNE] key, which operates in FM and DV modes. Other than these, the IC-905 is identical to the IC-705, so if you have the IC-705, you can operate it without any problems.

(Continued on the next page...)

Figure 02-6. Front panel of the IC-905 similar to the front panel of the IC-705

The interface on the side of the Controller in the IC-905 has been renewed from the IC-705. On the right side of the Controller, there is a connector for connection to the RF unit and digital interfaces such as USB, LAN, and SD card, while on the left side there are analog interfaces such as SP-MIC, EXT-SP, and video input/output for ATV. Note that even when the speaker plug of the supplied speaker microphone is connected to the [MIC-SP] jack, the Controller has been modified so that the user can select whether to output reception and operation audio from the built-in speaker or from the speaker-microphone.

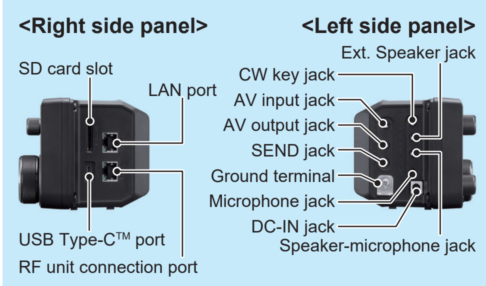

Figure 02-7. Side panels of the IC-905 Controller unit

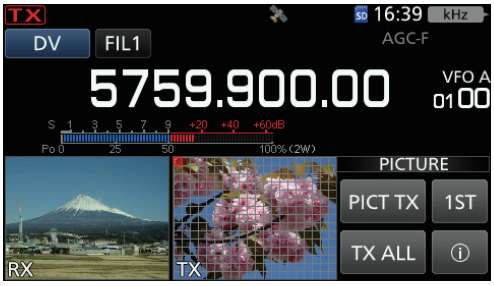

Figure 02-8. Example of image transmission in DV mode

The Controller digitally converts audio and ATV video signal, and outputs them to the RF unit after signal processing. The received digital signal output from the RF unit is also processed and then converted to analog and output as audio and ATV video signal.

Note that the IC-905 can display not only still images in DV mode, but also ATV video on the Controller.

In addition to these functions, the IC-905 Controller has another important role. It is to supply DC power to the RF unit. Even when using the optional controller cable, which is up to 50 m long, the 13.8 V supplied to the Controller is boosted to approximately 56 V before being supplied to the RF unit in order to minimize losses. The Controller contains many power-consuming devices such as display backlights, audio power amplifiers, DC-DC converters for power supply voltage boosting, and various power supply circuits. These devices also generate a lot of heat, so fins are installed on the rear side of the controller to dissipate heat.

Figure 02-9. Rear panel of IC-905 Controller unit with fins for heat dissipation

Why the 144 MHz and 430 MHz bands were included in the IC-905?

Before the announcement of the ICOM SHF Project in December 2021, when we started to develop the concept of an "SHF band amateur radio," we did not include the 144 MHz/430 MHz bands. However, we decided at the conceptual stage to include the 1.2 GHz band in the UHF band for communication during mobile operations in the SHF band.

We started designing the IC-905 based on this concept, but during the design process, we began to think, "If the IC-905 is not operated in the 1.2 GHz, 2.4 GHz, or 5.6 GHz bands, it could be used in the high activity 144 MHz or 430 MHz bands, so that it can be used more! This was the designer's thought. As this thought grew in intensity, we turned our attention once again to the Down-conversion IF Sampling Method used in the IC-905. As explained in "Direct Sampling Processing," RF signal up to 430 MHz band is directly converted to digital or analog by A/D and D/A converters. This is a circuit configuration that has been proven in the IC-9700.

Figure 02-10. Bands on which IC-905 can operate

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In other words, we thought that we could cover the amateur bands from 144 MHz to 5.6 GHz simply by incorporating 144 MHz and 430 MHz band RF circuits into the circuit configuration from the 1.2 GHz band to 5.6 GHz band. This idea led us to the decision to develop the IC-905 as an SHF band transceiver while also supporting the 144 MHz and 430 MHz bands.

Furthermore, after the announcement of the ICOM SHF Project, there were requests from domestic and overseas SHF users to cover the 10 GHz band at once. However, at that time, the structural design of the IC-905 had already progressed to some extent, so it could not be added within the RF unit. Instead, we decided to design the 10 GHz band as a transverter with the IC-905 as the parent unit. This 10 GHz band transverter is described in “CX-10G.”

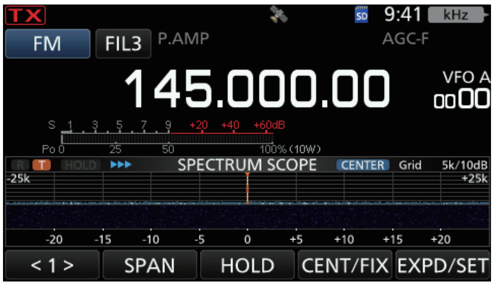

Figure 02-11. Display for the 144 MHz band operation

Support for SSB and AM

In recent years, VHF/UHF band mobile radios generally support D-STAR® in addition to the FM mode. Since the IC-905, an SHF-band radio, is not limited to fixed operation but is also intended for mobile and portable operations, we were particular about its ability to operate in various modes and started designing it as an all-mode unit with SSB/AM/CW as well.

In the early days, radio communications had its beginnings in CW. Voice radio communication originated in the AM mode, but the invention and spread of SSB and even FM reduced the opportunities for AM operation. However, AM has the characteristic that even if there is interference, both the target signal and the interference signal may be heard. AM also offers better audio quality than SSB, and, moreover, it offers the advantage of a narrower bandwidth for voice communications than FM.

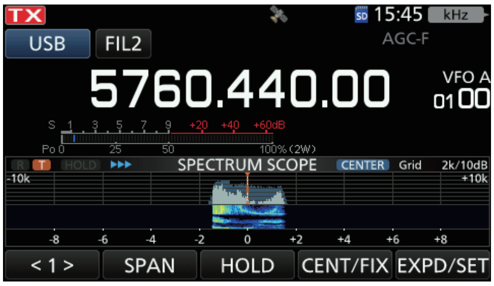

Figure 02-12. Displays transmit audio spectrum on SSB

For these reasons, Icom is committed to the CW mode, which marks the beginning of radio communications, and the AM mode, which marks the origin of voice communications, as modes of operation that cannot be dismissed in the history of radio communications and should be passed down to future generations.

However, in SSB and CW, the occupied bandwidth can be as narrow as several hundred Hz to 3 kHz, so frequency accuracy and signal purity are important. Even if the frequency deviation is the same, the absolute value of frequency error between the HF and SHF bands can be about 1,000 times the difference between megahertz and gigahertz. In addition, the higher the oscillation frequency of a local oscillation signal such as a VCO, the more difficult it becomes to ensure signal purity.

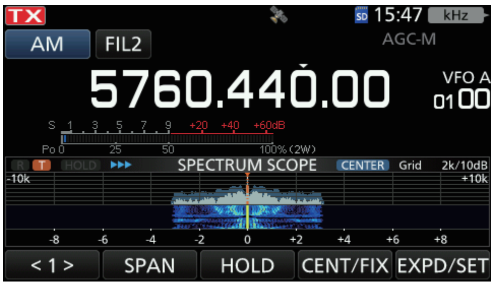

Figure 02-13. Displays transmit audio spectrum on AM

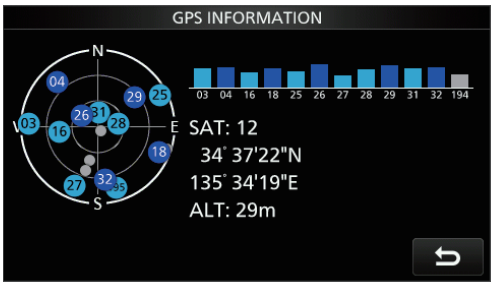

Figure 02-14. Displays GPS information

Therefore, the frequency accuracy utilizes the signals emitted from GPS satellites, and the purity of the local oscillation signal is achieved by using a configuration that combines a direct method circuit with a PLL/VCO device and a direct method circuit with D/A from a VCO circuit with LC, resulting in a significant improvement in performance. These are explained in separate sections.

New Features

The IC-905 offers the following new features unique to SHF band radio.

➥ FM ATV.

➥ Frequency management synchronized with GPS.

➥ Real-time spectrum scope extended to 50 MHz bandwidth.

These features are described in detail in their respective sections.

- PART 3 -

New Approach to SHF 03

Challenges to Development

Coaxial Cable Loss

In the SHF band, there are many circuit design issues, but there is also an unavoidable operational issue. That is transmission loss on the coaxial cable connecting the radio and antenna. As you know, the higher the frequency, the greater the loss of RF signal over the coaxial cable. Therefore, when operating in the 1.2 GHz band, it is common to use thicker cables with less loss than the coaxial cables used for operation in the 144 MHz and 430 MHz bands.

Figure 03-1. Various thicknesses of coaxial cable
(From the top, 8D-FB, 5D-2V, RG-58A/U, and RG-402/U (Semi-rigid))

In the 2.4 GHz and 5.6 GHz bands, the loss due to coaxial cables becomes even greater.

According to JARL (Japan Amateur Radio League) data, the loss of low-loss type 10D-FB at 2300 MHz is 1.95 dB/10 m.

Based on this data, the loss due to the coaxial cable is 3.9 dB when the antenna is connected to the radio with a 20 m 10D-FB cable. This means that even if 2 W power is transmitted from the antenna connector of the radio, only about 0.8 W is output at the antenna feed point. Although the data has not been published, if the 5.6 GHz band is operated under the same conditions, the loss on the coaxial cable will undoubtedly be even higher than in the 2.4 GHz band.

Here is an experiment on loss due to coaxial cable. Prepare 5D-FB, 5D-2V, and 8D-SFA-LITE coaxial cables. These The lengths of each are 66 cm, 20 m, and 20 m, respectively. Measure the loss when a 144 MHz, 430 MHz, and 1200 MHz RF signal is passed through each of these coaxial cables. Table 03-1 shows the measured loss of transmit power and Table 03-2 shows the measured loss of receive sensitivity.

Table03-1. Loss to transmit RF power

Coaxial cable	Transmit output power on FM (W)		
	1296.3MHz	433.1MHz	145.0MHz
5D-FB	1	1.02	1.02
5D-FB + 8D-SFA-LITE	0.56	0.74	0.855
5D-FB + 5D-2V	0.13	0.355	0.58

Table03-2. Loss to receive sensitivity

Coaxial cable	Sensitivity for 12dB SINAD on FM (dBμV)		
	1296.3MHz	433.1MHz	145.0MHz
5D-FB	–18.4	–18.3	–18.7
5D-FB + 8D-SFA-LITE	–15.5	–16.9	–17.9
5D-FB + 5D-2V	–9.2	–13.8	–16

These results show that the type and length of the coaxial cable connecting the radio and antenna has a significant effect on the transmission and reception performance. 2.4 GHz and 5.6 GHz bands have an even greater effect.

A solution to the coaxial cable loss

One way to compensate for the losses in the coaxial cable would be to increase the antenna gain. If it is possible to install a high-gain antenna, we would like to use it at that gain, but the power will be attenuated by the coaxial cable before it reaches the antenna. This is not a good use of a high-gain antenna. We examined other ways to reduce this "loss."

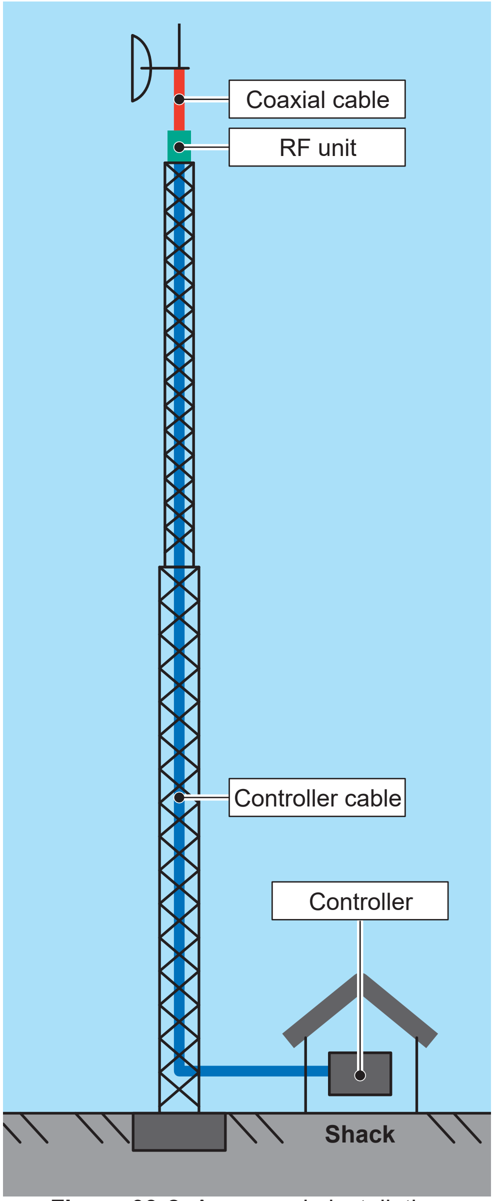

Figure 03-2. An example installation

One of the hints was the antenna-mounted type preamplifier to be installed for reception in the 1.2 GHz band. The antenna-mounted type preamplifier is a low-noise amplifier inserted directly under the antenna. In the same way, a linear amplifier with 2 W output power can be inserted directly under the antenna to compensate for the loss in the coaxial cable and feed power to the antenna.

Based on this idea, we thought that by placing the radio itself directly under the antenna, we could minimize the loss in the coaxial cable of the transmitted and received signals.

If the radio itself is installed directly under the antenna, the following issues can be identified

- ➡ The radio is directly installed under the antenna but operation should be indoors.
- ➡ The radio itself is exposed to wind and rain.
- ➡ How to supply power to the radio which consumes the most power.

As for "the radio unit is directly under the antenna, while the operation is indoors," we were able to handle the separate structure and control signal processing without difficulty, since we have a lot of experience with in-vehicle equipment.

For the "environment where the radio unit is exposed to wind and rain," we used our design know-how regarding waterproofing and weather resistance not only for portable units and outdoor antenna tuners, but also for inter-building communication units which are network equipment.

Figure 03-3. Icom BS-900, inter-building communication unit

The biggest challenge remained "power supply to the RF unit of the radio which consumes the most power." Assuming that the power supply voltage to the RF unit of the radio is 13.8 V, the current consumption is 4 A, and the distance from the shack to the RF unit of the radio placed directly under the antenna is 50 m. If the voltage drop in the power cable is to be kept below 0.5 V, the resistance value of the entire power cable must be 125 mΩ or lower.

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In other words, a power cable of 1.25 mΩ/m or less is required. However, if a copper wire of this specification as specified in the JIS (Japan Industrial Standard) is used, the outer diameter of the cable including the insulation coating is approximately 8 mm for a single wire, and the weight is approximately 17 kg, which is not realistic.

Here, we decided to use the PoE (Power on Ethernet) technology used in Icom's network equipment. Fortunately, we had experience with Ethernet cables (=LAN cables) and similar cables in a separate structure, so we decided to use them. The application of this PoE technology is explained in "Application of PoE++ Technology."

Application of PoE++ Technology

Since the IC-905 incorporates 1.2 GHz/2.4 GHz/5.6 GHz band circuits, the RF unit is designed to be installed directly under the antenna in order to minimize losses in the coaxial cable connecting the RF unit and the antenna. The separation technology developed for the Icom VHF/UHF mobile unit could be applied to the connection between the RF unit installed directly under the antenna and the controller installed in the shack. However, the power supply as a radio unit remains an issue.

The solution has been the application of PoE (Power over Ethernet) technology. In the separate structure used in Icom's VHF/UHF mobile units, we have a proven track record regarding the connection of the controller and RF unit using a cable fitted with the same RJ-45 type connector as the LAN cable.

Although power is also supplied in this connection, it is from the RF unit to the controller, and its power is very low at the several W level.

Furthermore, the network equipment handled by Icom is IEEE802.3af compliant even with PoE, so the maximum amount of power is 15.4 W. Therefore, the problem was how to supply the tens of watts of power required by the IC-905.

Figure 03-4. AP-900 designed in accordance with IEEE802.3af

We applied a technology equivalent to PoE++ (IEEE802.3bt / maximum power supply: approx. 90 W) using a standard that can supply even more power than PoE.

Note: The PoE++ technology applied in the IC-905 is not compatible with the IEEE802.3bt standard PoE++.

With the application of this technology, the Controller is supplied with 13.8 V DC which is commonly used in amateur radio equipment, and the 13.8 V DC is boosted to approximately 56 V by a DC-DC converter inside the Controller to supply up to 70 W of power to the RF unit.

In the RF unit, the supplied power is controlled and generated by the controller IC to supply power such as 12 V DC to each block in the RF unit.

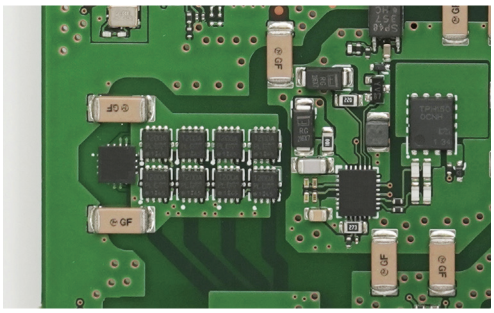

Figure 03-5. Inside view of the PoE circuit board on the RF unit

Issue of the frequency stability on SHF

In recent years, RF signal is generally generated directly at the target frequency by PLL or D/A converter. This is because the reference clock frequency which is the source of the frequency is stable. An error of 0.5 ppm to 10 MHz is 5 Hz which is not a big problem in actual operation in the HF or VHF band, but at 1280 MHz, the error is 640 Hz. The error of SSB cannot be demodulated correctly, and when it comes to CW, the received signal may be outside the filter and cannot be received. Even if a TCXO (Temperature Controlled X'tal* Oscillator) which is said to have relatively high accuracy is used as a reference oscillator, if its accuracy is 0.5 ppm, the same frequency fluctuation will occur. At 5700 MHz, this would be as high as 2850 Hz, and there is a possibility that even SSB would not be able to receive the signal.

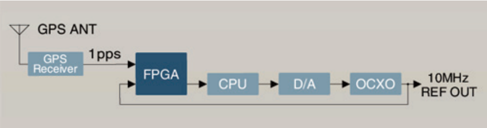

Figure 03-6. Block diagram of GPSDO (GPS Disciplined Oscillator)

The solution to this problem is to use an OCXO (Oven Controlled X'tal Oscillator) which is also used in IC-7850/IC-7851, and with this method, frequency stability can be suppressed to 0.05 ppm. This method can also be used to drastically reduce the frequency error to 0.05 ppm.

*X'tal=Crystal

Even with this method, strictly speaking, the oscillation frequency will gradually change over a long period of time due to changes in temperature and aging. It is also not easy to prepare a reference signal for frequency calibration. In addition to this, D-STAR® was the reference for the IC-905's solution to frequency stability. The IC-905 supports D-STAR® operation, and if the radio is D-STAR® compatible, it also supports the ability to send and receive location information using GPS. As D-STAR® radios have a GPS receiver built into the radio to use this function, the radio to capture pulse waves (1PPS signals) from the very accurate time signals fired from GPS satellites. By utilizing this highly accurate pulse wave, a highly accurate 10 MHz reference signal can be generated inside the radio.

In other words, the built-in GPSDO (GPS Disciplined Oscillator) compares and manages this 1PPS signal and the oscillation signal of the OCXO in the FPGA to further improve the accuracy and stability of the 10 MHz reference signal. By improving the accuracy and stability of the 10 MHz reference signal, high accuracy and high stability can be ensured even in the 5700 MHz band.

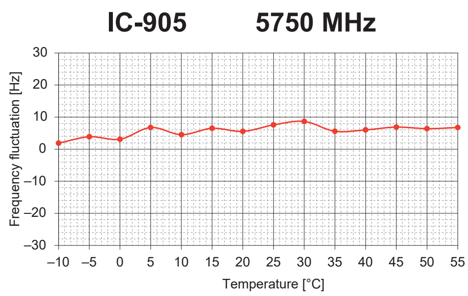

Figure 03-7. IC-905 (OCXO+GPS) frequency-temperature characteristics

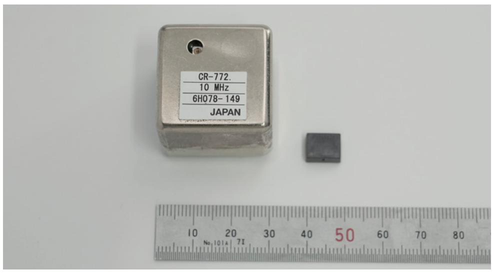

Figure 03-8. Size comparison with conventional OCXOs

(Left: for IC-7800, Right: for IC-905)

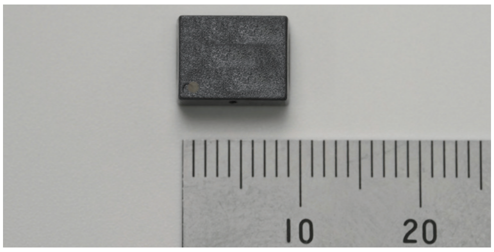

Figure 03-9. OCXO unit installed in the IC-905

Note that because of the large size of conventional OCXOs, it took time for the temperature of the oscillator itself to stabilize, and as a result, it took time for the oscillation frequency to stabilize.

However, the OCXO used in the IC-905 is about 10 mm square, so it can achieve practical frequency accuracy in a short time after power ON. Furthermore, by receiving a GPS signal, it makes the reference frequency to stabilized to a high degree of accuracy.

By using this highly accurate and stable 10 MHz reference signal, OCXO achieves an amazing ±65 ppb* overall frequency stability in all frequency bands, including environmental temperature/age deviation.

This 10 MHz reference signal is also used as a reference signal for the CX-10G, a 10 GHz transverter.

* ppb: Abbreviation for parts per billion. It is 1/1000 of the common ppm (parts per million: million fractions).

Wideband real-time spectrum scope

The VHF/UHF transceiver IC-9700 is also equipped with a spectrum scope function, but the frequency range (span) that can be displayed on the display is 1 MHz. It is not possible to see the entire band for the UHF band on the screen.

Furthermore, FM-ATV has an occupied bandwidth of several MHz or more, so a spectrum scope with a 1 MHz span cannot show the entire band.

This led us to expand the span of the IC-905's spectrum scope display to a maximum of ±25 MHz. In the IC-9700 operation, each time [SPAN] is touched, the span expands, but the IC-905 has a usage that the span width can be set by touching [+]/[–].

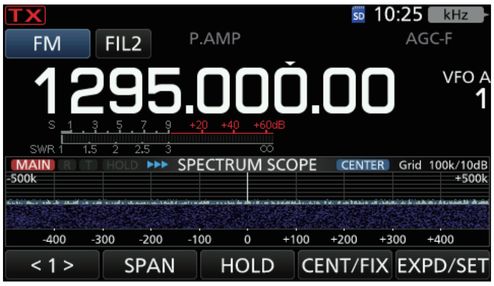

Figure 03-10. Maximum span of the IC-9700 for ±500 kHz

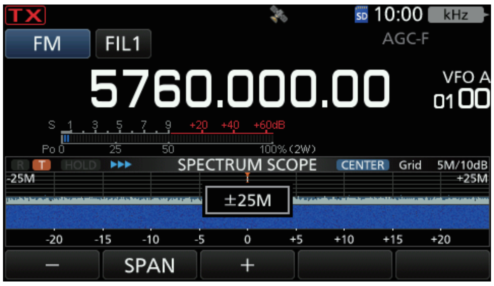

Figure 03-11. Maximum span of the IC-905 for ±25 MHz

Equipped with ATV function

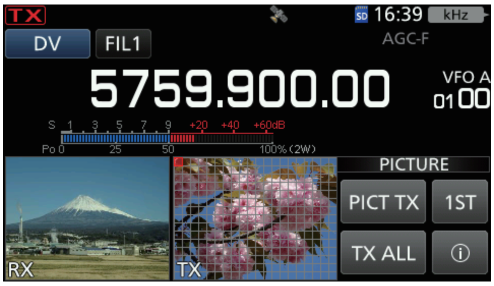

Figure 03-12. Example of receiving image transmission in DV mode

Narrowband image transmission is performed in SSTV (Slow Scan Television) and DV modes for D-STAR®, but these images are still pictures. Real-time video transmission is limited to the 1.2 GHz band and above, The IC-905's broadband SHF band allows users to enjoy video transmission.

For about 40 years, Icom has offered optional ATV units such as the TV-1200 for connection to the IC-1271, a 1.2 GHz band amateur radio, and the TV-1275 for connection to the IC-1275. In recent years, some communications are being done via digital ATV in HD (High Definition) quality, and the IC-905 offers ATV functionality using FM (frequency modulation).

There are two reasons why FM was selected for ATV. First, it can transmit real-time video without delay. The other is to be able to receive images from FPUs (Field Pick-up Units) used for relaying broadcast material and FPVs (First Person View) in the 5 GHz band used by drones and other devices. However, due to the digitalization of FPUs for broadcasting business, FM-TV may be almost impossible to receive.

In addition, while AM ATV is limited to 2.5 W carrier power in the 1.2 GHz band and 0.5 W in the 2.4 GHz/5.6 GHz bands. FM ATV can operate with 10 W in the 1.2 GHz band and 2 W in the 2.4 GHz/5.6 GHz bands four times higher transmitting power than AM. This is a big advantage.

For reference, there are three major ATV broadcasting systems: NTSC, PAL, and SECAM.

There are also multiple subcarrier frequencies for audio signal. Although it is difficult to support all systems and subcarrier frequencies but switching between the major NTSC, PAL, and SECAM systems is automatic depending on the received signal. The subcarrier frequency can also be selected from six subcarrier frequencies: 4.5 MHz, 5.5 MHz, 6.0 MHz, 6.5 MHz, 7.02 MHz, and 7.2 MHz.

Figure 03-13. IC-1275 and TV-1275

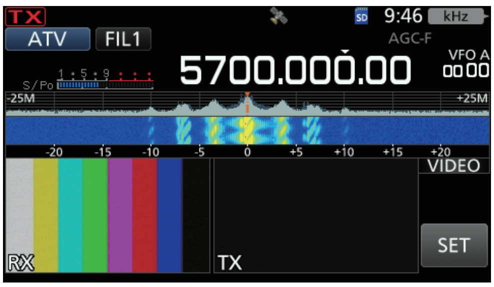

Figure 03-14. An example screen capture on the IC-905 for ATV test image

RF unit

Transmit signal generation and phase noise

Generally speaking, the higher the oscillation frequency, the more oscillator phase noise is generated. Therefore, it is inevitable to ensure good transmit phase noise characteristics for an all-mode radio that covers a high frequency range from VHF to SHF bands, such as the IC-905. In the development of the IC-905, we decided to use the circuit configuration of the IC-9700 as the basis for the IC-905. Since the IC-9700 has a proven track record of obtaining good transmit phase noise characteristics up to the 1.2 GHz band.

In the 144 MHz and 430 MHz bands in the IC-9700, the operational frequency is directly generated by a D/A converter. On the other hand, in the 1.2 GHz band, the D/A converter generates the IF (Intermediate Frequency) signal in the 351 MHz band and mixes it with LO (Local Oscillator) signal generated by the PLL/VCO to create a low phase noise 1.2 GHz band transmit signal.

In the 2.4 GHz band/5.6 GHz band, the 1.2 GHz band signal is used as the IF signal, and the target frequency signal is generated by mixing it with a LO signal generated by another PLL/VCO. To generate a low phase noise transmit signal, the phase noise of the LO signal input to the mixer must also be low.

For this reason, the IC-905 uses a crystal oscillator that generates a reference frequency signal in the 196 MHz range input to the PLL/VCO, as well as a PLL-controlled VCXO with high stability and low phase noise characteristics while selecting the optimal PLL/VCO and mixer device.

The 10 MHz reference signal used for this PLL control is a signal with high accuracy and low phase noise characteristics using GPSDO technology.

As described above, the IC-905 is designed with a focus on high transmission signal quality even for SSB operation in the GHz band.

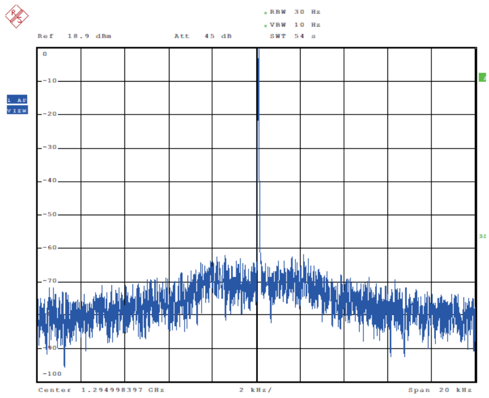

Figure 03-15. Transmit signal spectrum of the IC-910 at 1295 MHz

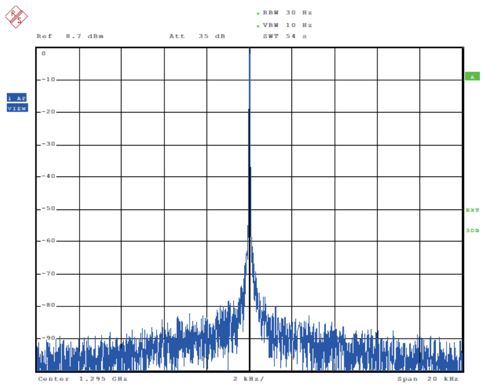

Figure 03-16. Transmit signal spectrum of the IC-905 at 1295 MHz

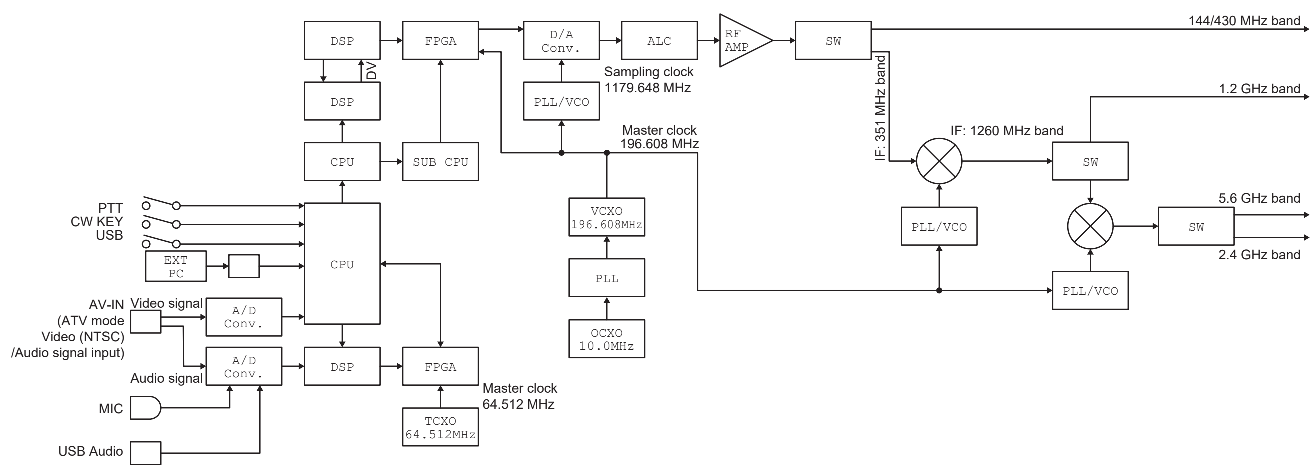

Figure 03-17. Block diagram of the frequency generation circuit.

Selection of devices for use

◆ LDO (Low DropOut)

LDO linear regulators with low noise are used for IO power supplies for FPGAs and analog circuits. Although LDO linear regulators are considered to have lower power conversion efficiency than general DC-DC switching regulators, they are adopted because of their overwhelmingly low noise.

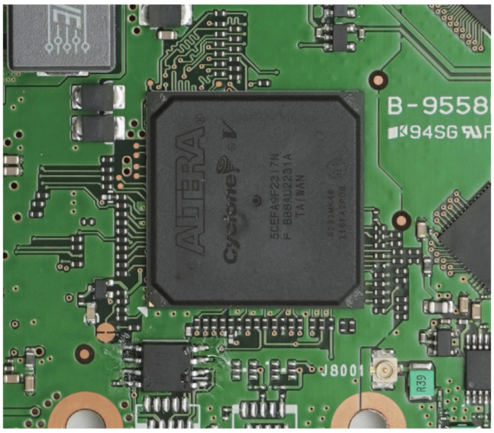

Figure 03-18. FPGA used in the IC-905

◆ FPGA

FPGA stands for Field Programmable Gate Array, a device that can be programmed to change the configuration of digital circuits.

For example, an oscillator normally configured as a digital circuit can be turned into a filter or mixer by changing the program.

Furthermore, it is a multi-purpose device that can change the oscillation frequency of the same oscillator or, in the case of a filter, the center frequency, bandwidth, and characteristics of the filter. This device can be said to be a collection of digital circuits.

Icom has more than 30 years of accumulated signal processing technology using DSP. However, in the process of pursuing more advanced radio functions and reception performance with a wider dynamic range, the amount of digital signal processing in dedicated DSP devices has greatly increased, and the processing configuration blocks have become more complex. For this reason, Icom’s recent all-mode models have adopted a large-scale FPGA, and the IC-905 is also equipped with this FPGA in order to be designed as an all-mode transceiver in the SHF band.

◆ A/D and D/A converters

Device selection for A/D (Analog to Digital) or D/A (Digital to Analog) converters is based on the sampling theorem. The sampling theorem is relative to the conversion speed (= sampling rate) required to convert digitally. Also, even A/D converter and D/A converter are mostly analog devices except for the blocks that handle digital signals. Therefore, the same design considerations as for transistors and FETs are required. As key points in device selection, we focused on SNR (Signal-to-Noise Ratio) and SFDR (Spurious Free Dynamic Range) which affect dynamic range in addition to sampling rate, and compared and examined each device.

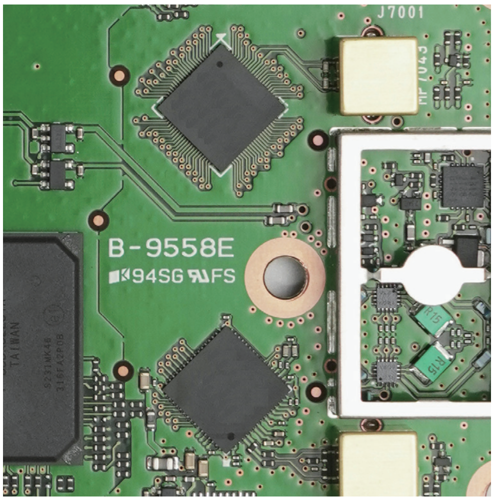

Figure 03-19. D/A converter (Upper) and A/D converter (Lower)

Although the performance of A/D converter is generally focused on the number of bits, SNR and SFDR are important factors for direct sampling receivers. SNR is the ratio of the noise level to the signal level, sometimes expressed as S/N ratio or just S/N. The units are usually expressed in logarithms and expressed in “dB,” but when the signal is calculated as a full-scale value, it is expressed in “dBFS.”

The output of an A/D converter is a digital signal, but the output signal contains noise (quantization noise). This quantization noise is affected by the resolution, or number of bits (N), and can be expressed as SNR=6.02N+1.76 (dB)* as a theoretical value, but it is actually less than the theoretical value.

*Calculation formula for a sinusoidal signal input with no noise other than quantization noise.

A/D converters also generate distortion (spurious components) due to their non-linearity. The SFDR value of an A/D converter is expressed as the ratio of the level of the carrier to the largest component of the distortion component generated when the carrier is input. The unit is usually “dBc” because it is a logarithm based on the carrier (=carrier), but it may also be expressed simply in “dB” by taking the logarithm alone. After comparing and verifying various A/D converters, we have come to adopt the most suitable device for the IC-905.

◆ PLL and VCO

A previous model, the IC-910 used discrete components such as transistors, coils, and capacitors to make PLL and VCO circuits. Since these components were mounted on a PCB (Printed Circuit Board), even in the 1.2 GHz band, C/N characteristics were also limited due to the influence of patterns on the PCB. In recent years, however, there are many devices in which the PLL and VCO are packaged in one chip. From among these devices, we have selected the most suitable device for the IC-905, taking into consideration performance such as C/N characteristics and availability.

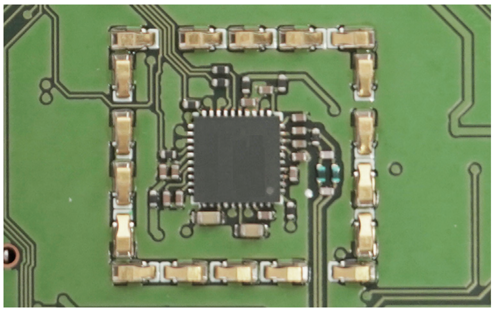

Figure 03-20. Device of PLL/VCO used in the 1.2 GHz band.

◆ Mixer

Mixers that can be used in the 2.4 GHz and 5.6 GHz bands are also available as ICs from semiconductor manufacturers. We evaluate them in the same way as PLL/VCO devices and select the most suitable device from among them.

◆ Transmit final power amplifier

Power amplifier devices in the 2.4 GHz and 5.6 GHz bands are easily selected and obtained because of the wide variety of devices available from various companies in line with the spread of wireless LAN. Therefore, by combining the outputs of several devices in a Wilkinson circuit, it is now possible to obtain a 2 W transmit output at the antenna connector end.

On the other hand, for the power amplifier in the 1.2 GHz band, we were considering using devices mainly used in the 900 MHz band, but unfortunately, the results of our experiments showed that they were not efficient enough to provide sufficient transmit power with the power supply provided by the application of PoE technology.

Fortunately, around the same time, AMPLEON proposed a high-efficiency LDMOS (P1dB=43dBm @ 65% efficiency) with a supply voltage of 25 V tuned at 1.2 GHz.

The result of the experiment showed good characteristics, and we decided to adopt it as a 10W power amplifier device.

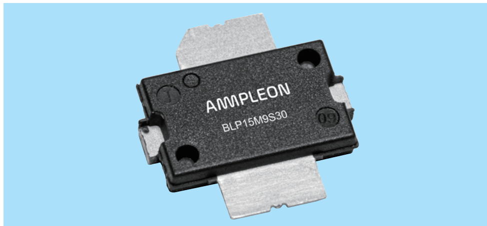

Figure 03-21. Transmit final power amplifier for the 1.2 GHz band.

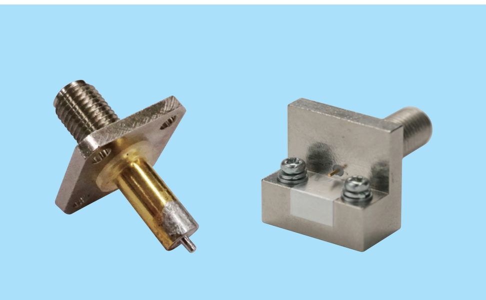

Figure 03-22. Custom-designed antenna connectors.
(Left: for 5.6 GHz band, Right: for 10 GHz band)

◆ Antenna connector

We explained that the IC-905 was designed to install the RF unit directly under the antenna in order to minimize losses in the coaxial cable for 1.2 GHz, 2.4 GHz and 5.6 GHz band operations. Therefore, it was necessary to fix all antenna connectors including the one for GPS to the enclosure (aluminum diecast housing) of the RF unit.

Installing the RF unit directly under the antenna means that it must be waterproof. Generally, to ensure waterproof performance, waterproof rubber gaskets are used at the mating part with the enclosure. The general waterproof rubber gasket is non-conductive. Using a waterproof rubber gasket between the enclosure and the antenna connector will prevent the antenna from being sufficiently grounded to the enclosure GND. In particular, the 2.4 GHz and 5.6 GHz bands, as well as GPS antennas will not be able to achieve impedance matching with the inside of the RF unit.

The IC-905 solves this problem by employing a custom-designed antenna connector to ensure water resistance and impedance matching between the 2.4 GHz, 5.6 GHz, and GPS antennas and the RF unit circuit.

Structure and installation of the RF unit

The radio converts RF signals received by the antenna into audio signals. The microphone audio signals are converted into an RF signal. In these processes, heat is generated due to the conversion loss at the various stages .All electrical appliances generate heat due to the loss. For example, in mobile radios and fixed radios, cooling fans are mounted on the heat sink to dissipate or cool this heat forcing it to cool down.

Figure 03-23. A large cooling fan installed in the IC-9700

Figure 03-24. Heat dissipation fins on IC-905 RF unit

However, the RF unit of the IC-905 is designed to be installed outdoors directly under the antenna, and its waterproof construction makes it difficult to forcibly cool the heat generated in the RF unit with a cooling fan.

Therefore, the entire RF unit is made of aluminum diecast, and the heat generated inside is naturally dissipated outside by the diecast. Large heat dissipation fins are integrally molded into this diecast to achieve good heat dissipation efficiency.

The RF unit can be easily installed directly under the antenna by using a special bracket to ensure sufficient strength. Furthermore, the antenna connector is mounted on the top of the RF unit so that the coaxial cable used to connect the antenna to the RF unit is kept to the shortest length possible, thereby reducing losses as much as possible.

To ensure safety when installing the RF unit to the pole, we also paid special attention to the mounting bracket. The RF unit uses a structure that hooks onto the bracket. This structure makes it very easy to install the RF unit on the pole.

First, fix the bracket to the pole. Then, four screws are loosely attached to both sides of the RF unit. After that, hook the RF unit to the bracket, then tighten four screws to prevent the RF unit from falling. The RF unit is firmly positioned, and the loose screws are tightened. The RF unit can be installed on the pole relatively easily.

This structure is also convenient for mobile operations where the RF unit is frequently attached and detached.

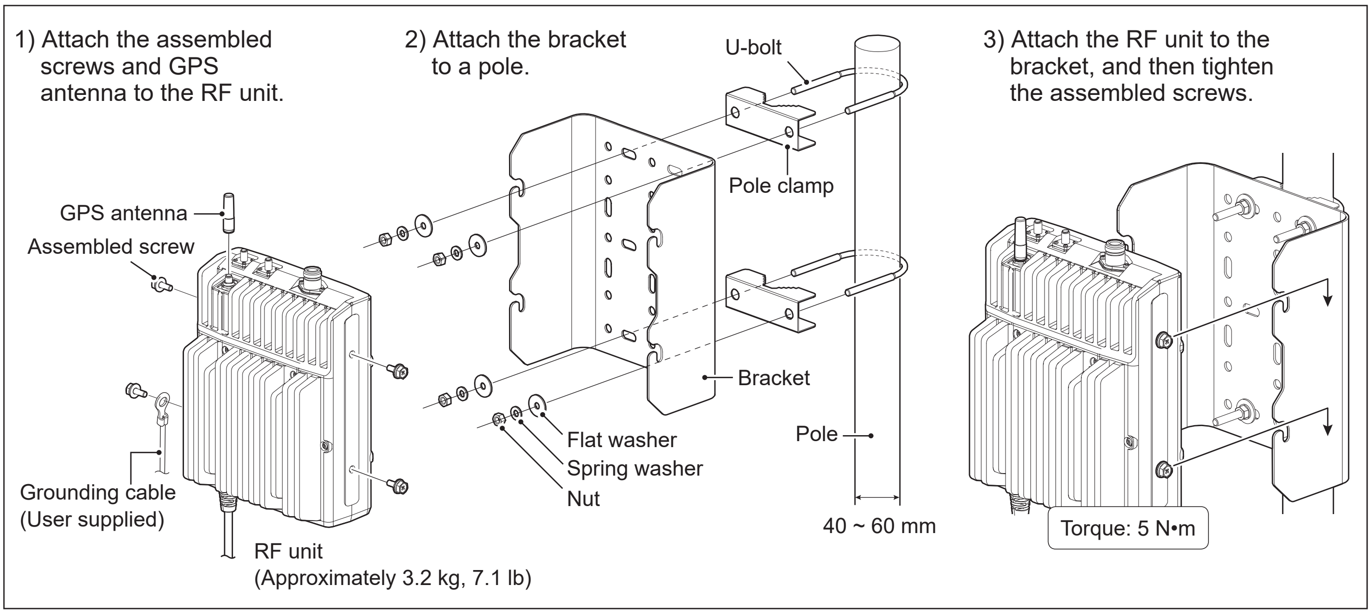

Figure 03-25. RF unit installation instructions. (Excerpts from the Connection Guide.)

Controller hardware design

The shape of the IC-905 Controller is that of the IC-705 without the battery pack. The IC-705's housing was a transceiver that incorporated an operating unit, a transmitter, and a receiver, but the IC-905 only has a Controller unit that performs operations, so it does not incorporate RF circuitry.

The main components in the Controller are an interface that digitizes AF signals and communicates with the RF unit, and a power supply circuit that supplies DC power to the RF unit. The power supply circuit for the RF unit is based on PoE++ technology, as explained earlier. At the beginning of the design process, the circuit was designed with a slight power-up based on a circuit that has a proven track record in network equipment. However, as the specifications and performance of the IC-905 improved, an even larger power supply of about 70 W became necessary, so we made major changes to the design of the housing of the Controller section, and a heat sink was installed on the surface where the battery pack was attached in the IC-705. The circuit design has also been changed to make the SD card and speaker microphone easier to use.

Figure 03-26. A heat sink is installed on the rear panel of the IC-905

- PART 4 -

Mechanical Design 04

Evaluation of enclosure temperature

At the conceptual stage of the IC-905, the Controller section was to be housed in the housing of the IC-705, including the control and power supply circuits of the RF unit, display circuit, and audio amplifier. In the initial stage, a relatively simple shape was considered for the RF unit, as shown in Figure 04-1.

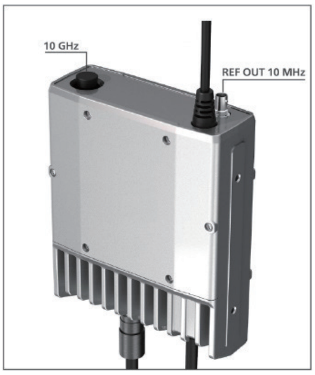

Figure 04-1. Initial RF unit design proposal

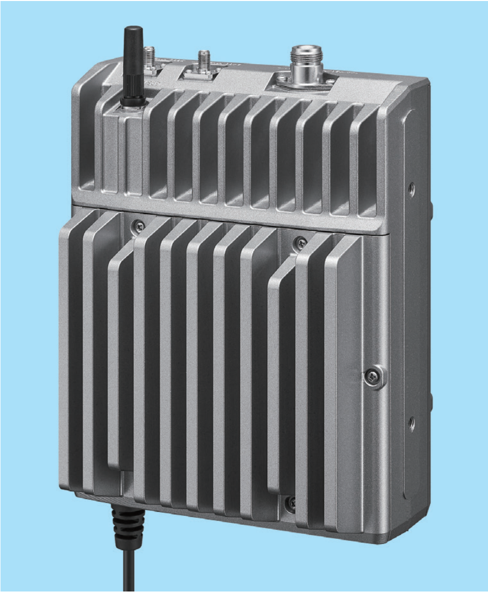

Figure 04-2. Appearance of the final version of the RF unit.

However, as explained in the initial conception, it was decided to increase the transmission output power of the 1.2 GHz, 2.4 GHz, and 5.6 GHz bands to the upper limits specified by the Japanese Radio Law. This raised the issue of increasing the power supply capacity built into the Controller to be operated in the shack and the accompanying heat generation, as well as the measures to deal with the heat generated by the increased transmission output of the RF unit. In particular, since the RF unit is installed directly under the antenna, a solar radiation test was conducted as shown in Figure 04-3, taking into consideration the effects of direct sunlight. On the other hand, since the RF unit is exposed to wind and rain, we decided to use natural heat dissipation by a heat sink, instead of cooling by fans. The heat dissipation of the controller operated inside the shack was similarly addressed by the addition of a heat sink.

◆ Conformity to new safety standards including fire

In particular, we verified the conformity of the IC-905 RF unit to the new safety standards, including fire due to electrical factors. As a result, we confirmed that the RF unit complies with the safety standard.

We have also verified that there is no problem with temperature rise, which is one of the causes of failure, by testing under conditions assuming the installation environment, at the time of design.

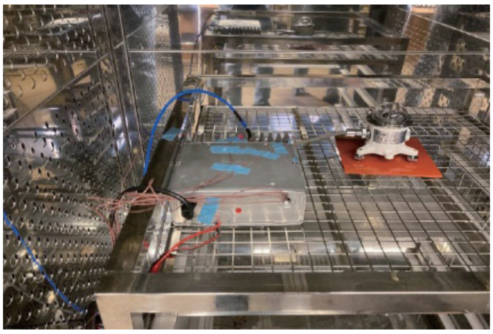

Figure 04-3. Solar Radiation Testing

- PART 5 -

05 Operations

Radio propagation in the SHF band

The higher the frequency, the more direct the propagation of signals becomes, and in many cases, signals cannot reach beyond obstacles.

Even when there is a clear line of sight between two communicating stations, changes in weather conditions, from sunny to rainy or foggy, or the presence of obstructions will attenuate the electric field strength of the communication and shorten the communication distance. In extreme cases, communication may become impossible.

This explanation may lead to the misconception that SHF-band signals do not reach far, but in actual operation, signals are subject to diffraction and reflection, so communication is possible even in places that cannot be seen. We verified this in field operations. The results are explained below.

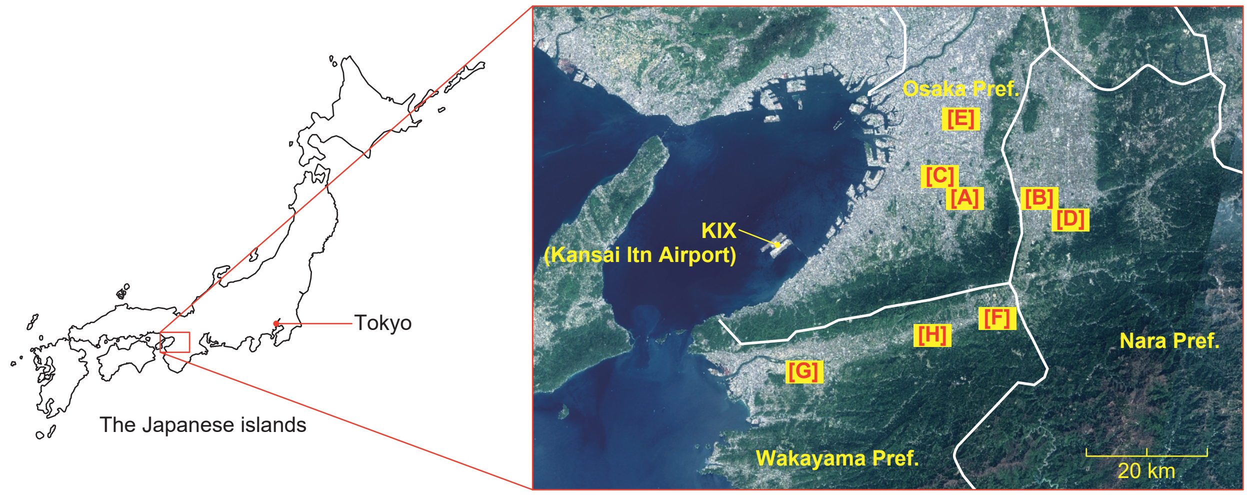

Figure 05-1. Field operation points— Wide view

(These figures are based on data from the Geospatial Information Authority of Japan.)

Point [A]	Kanan-cho, Minami Kawachi-gun
Point [B]	Oshimi, Katsuragi City
Point [C]	Sayama Pond, Osaka-Sayama City
Point [D]	Shimoyatsuri, Kashihara City
Point [E]	Hirano-ku, Osaka City
Point [F]	Koino, Hashimoto City
Point [G]	Kishikawa-cho, Kinokawa City
Point [H]	Katsuragi-cho, Ito-gun

1. Propagation test between points in Osaka and Nara prefectures

Osaka prefecture is open to Osaka Bay to the west, but the northern, southern, and eastern parts of the city are surrounded by mountains ranging from a few hundred meters to a thousand or more meters high. Although communication between Osaka and neighboring prefectures is not good on UHF or SHF, we have experimented with radio propagation over the mountains.

We tried communication between Osaka and Nara, and then between Osaka and Wakayama. The results are shown below.

		Osaka Pref.	Nara Pref.
Location of operation		[A]	[B]
		[C]	[D]
Transceiver		IC-905XG	
Antenna	1200 MHz	17-element Loop Yagi	16-element Yagi (16.6 dBi)
	5600 MHz	Meshed type parabolic antenna (30 dBi)	
	10 GHz	Icom AH-109PB Solid type parabolic antenna (31 dBi)	

Figure 05-2. A view from location [A] looking in the direction of the other station to be communicated with.
A 700-meter-high mountain rises in the foreground.

Figure 05-3. A view from location [B] looking in the direction of the other station to be communicated with.

Table05-1. Signal strength shown in the IC-905 S-meter

Communication points		[A]↔[B]	[C]↔[B]	[C]↔[D]
Communication distance		10.0 km	17.4 km	25.0 km
Band operated (RF power)	1200 MHz (1W)	S6	S6	S7
	5.6 GHz (2 W)	S7	S6	S5
	10 GHz (0.5 W)	S1	S5	S3

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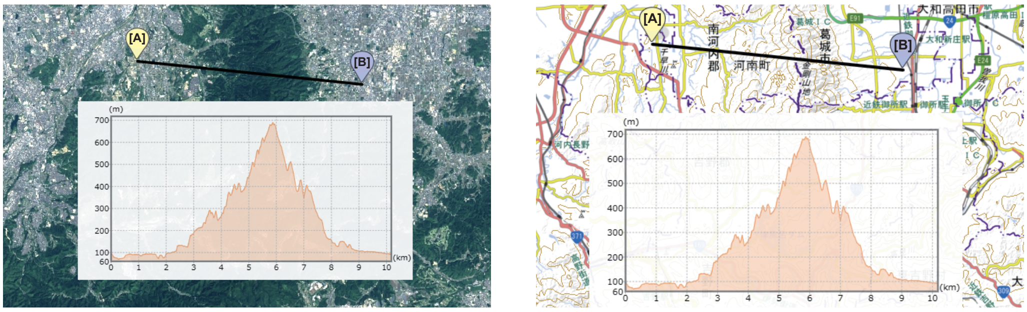

Figure 05-4. Mountain height information (between [A]: Kanan-cho and [B]: Katsuragi City)
(These figures are based on data from the Geospatial Information Authority of Japan.)

2. Propagation test between points in Osaka and Wakayama prefectures

There is also a mountain range on the border between Osaka and Wakayama prefectures from east to west. This is a communication experiment between two points in the mountain range at an altitude of about 700 m above sea level. The locations and facilities of the two communicating stations are as follows.

		Osaka Pref.	Wakayama Pref.
Location of operation		[E] (Key station)	[F]
		[C]	[H]
		–	[G]
Transceiver		IC-905XG	
Antenna	1200 MHz	GP (11.7 dBi) / 16-element Yagi (16.6 dBi)	17-element Loop Yagi
	5600 MHz	Meshed type parabolic antenna (30 dBi)	
	10 GHz	Icom AH-109PB Solid type parabolic antenna (31 dBi)	

Figure 05-5. A view from location [C] looking in the direction of the other station to be communicated with.

Figure 05-6. A view from location [F] looking in the direction of the other station to be communicated with.

Table05-2. Signal strength at each point when a signal is transmitted from point [E].

Communication points		[E]↔[F]	[E]↔[H]	[E]↔[G]
Communication distance		35.1 km	38.5 km	52.2 km
Band operated (RF power)	1200 MHz (1 W)	No communication		
	5600 MHz (2 W)	RS 52	RS 54	RS 51 ~ 52
	10 GHz (0.5 W)	RS 51	RS 56	RS 41

RS: Readability and Signal strength.

Table05-3. Signal strength at each point when a signal is transmitted from point [C].

Communication points		[C]↔[F]	[C]↔[H]	[C]↔[G]
Communication distance		23.6km	25.5km	40.1km
Band operated (RF power)	1200 MHz (1 W)	RS 56 ~ 57	RS 55 ~ 56	RS 55
	5600 MHz (2 W)	RS 57	RS 52 ~ 54	RS 54
	10 GHz (0.5 W)	RS 55	RS 55	RS 51 ~ 53

RS: Readability and Signal strength.

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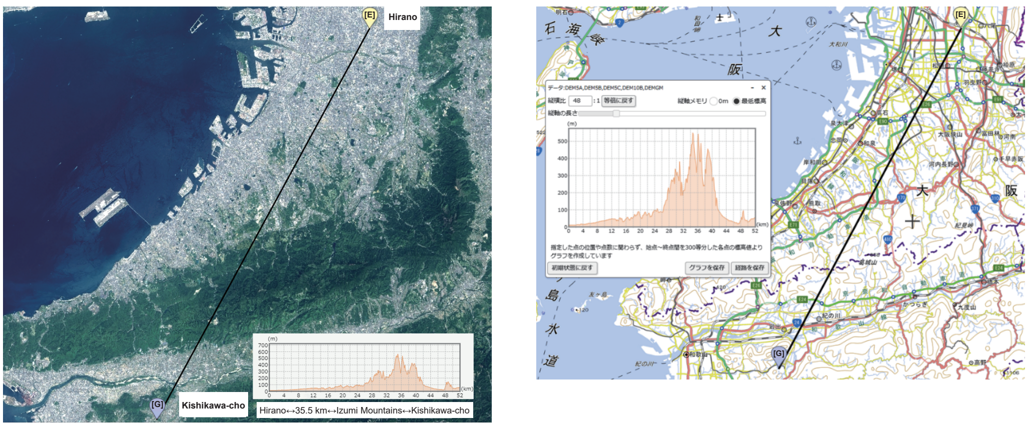

Figure 05-7. Mountain height information (between [E]: Hirano-ku and [G]: Kishikawa-cho)
(These figures are based on data from the Geospatial Information Authority of Japan.)

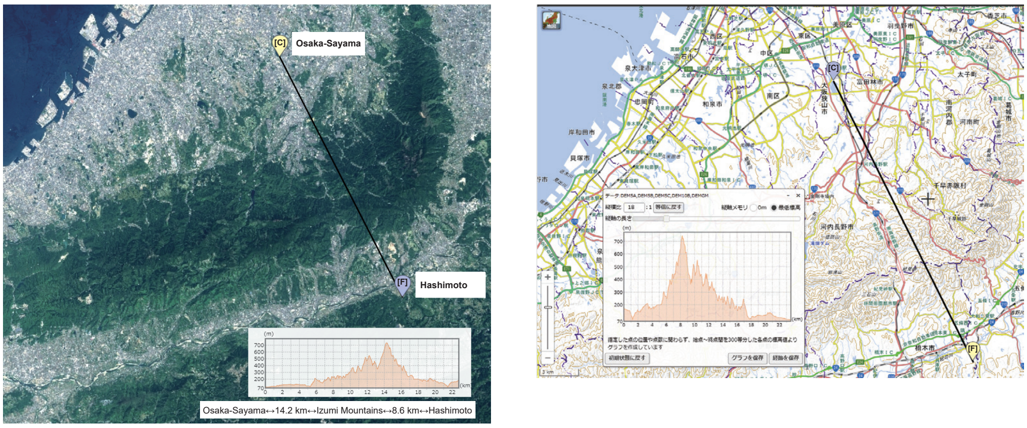

Figure 05-8. Mountain height information (between [C]: Osaka-Sayama and [F]: Hashimoto)
(These figures are based on data from the Geospatial Information Authority of Japan.)

The results of these radio propagation experiments indicate that if only one mountain ridge is crossed from each of the two communication points, there is a high possibility of communication by mountain diffraction. However, this verification was done by checking on a map in advance and by using a high-gain parabolic antenna to account for signal attenuation due to diffraction.

Signals are scattered and reflected by various objects, so signals may be received from unexpected directions. If the operation is in an urban area, it is possible to expect communications from scattered reflections from buildings and other structures.

In addition, out-of-sight communications by rain scatters and radio ducts are also possible. In this way, communication depending on weather conditions is one of the ways to enjoy SHF band communication. In fact, many SHF users communicate using these mountain diffraction and scatter reflections.

Wireless LAN and Bluetooth®

The IC-705 is equipped with wireless LAN (Wi-Fi®) and Bluetooth® for connection to other external devices. However, the IC-905 has neither wireless LAN nor Bluetooth®. Any amateur radio operator familiar with the band plan will understand why. That is because Wi-Fi® and Bluetooth® are assigned to one of the IC-905's operational bands in the 2.4 GHz band.

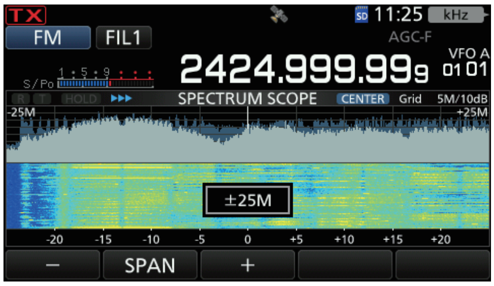

Figure 05-9. Spectrum of the 2.4 GHz band in urban areas

The IC-905 spectrum scope can confirm that many signals are being emitted

Figure 05-10. Icom VS-3 Bluetooth® Headset

Services such as "Free Wi-Fi®" are offered everywhere, including cafes and restaurants. Bluetooth® is used to wirelessly connect cell phones and smartphones to hands-free headsets and stereo headphones. As a result, urban areas are inundated with the 2.4 GHz band. There are areas where these signals cannot reach, such as on high ground or on mountains with good views away from urban areas. However, when the IC-905 is operated with wireless LAN or Bluetooth®, it is subject to interference from these signals during 2.4 GHz band operation. In addition, use of the 2.4 GHz band is restricted in many countries to primary and secondary operations, and amateur radio is a secondary operation. Secondary operations are restricted to those that do not interfere with reliable communications conducted in the primary operations. When a wireless LAN or Bluetooth® is incorporated in the IC-905, the signals emitted from the incorporated circuitry will interfere with 2.4 GHz operation. For this reason, the IC-905 is purposely not equipped with wireless LAN and Bluetooth®. Therefore, especially when operating in the 2.4 GHz and 5.6 GHz bands with the IC-905, we recommend turning OFF Wi-Fi® and Bluetooth® devices such as your PC, smartphones, and wireless router in your home to reduce the risk of interference from these devices before operation.

- PART 6 -

Deployment to the Higher SHF Band 06

CX-10G 10 GHz Transverter

When the IC-905 was first developed, it was designed as a transceiver covering five bands from 144 MHz to 5.6 GHz. After Icom announced the "ICOM SHF Project" on its website, there was a strong demand from SHF band enthusiasts, so we also began designing a CX-10 Transverter to cover the 10 GHz band.

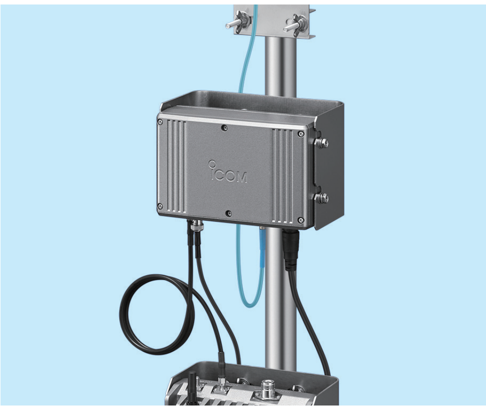

Figure 06-1. CX-10G 10GHz Transverter

The transverter generates a signal of the target frequency by mixing two signals. To obtain a 10 GHz signal, two signals are required: an IF signal supplied by the IC-905 and a local oscillator signal generated in the CX-10G. For the IF signal, 2.4 GHz was chosen in consideration of the spurious signal that is generated when mixed with the local oscillator signal and the frequency range that can be output from the IC-905.

For the internal reference signal, the highly accurate and low phase noise of the 10 MHz signal from the IC-905 obtained by GPSDO technology is used as the reference signal. This reference signal is used to generate a reference signal (122.88 MHz) for the local oscillation circuit by the PLL and VCXO inside the CX-10G, and a high-precision local oscillation signal from 7600 MHz to 8050 MHz is generated by the PLL/VCO based on this 122.88 MHz reference signal.

Generating local oscillation signal, mixing with the IF signal, amplifying the mixed signal to get the transmit power, and providing it to the antenna are processed on a single PCB (Printed Circuit Board). The RF filter between the amplification stage and the antenna output is also configured on the same board as shown in Figure 06-2.

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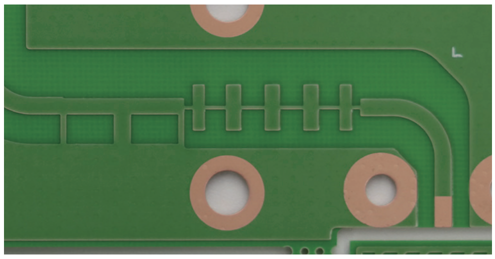

Figure 06-2. RF filter between the amplification stage and the antenna terminal, made as a PCB pattern

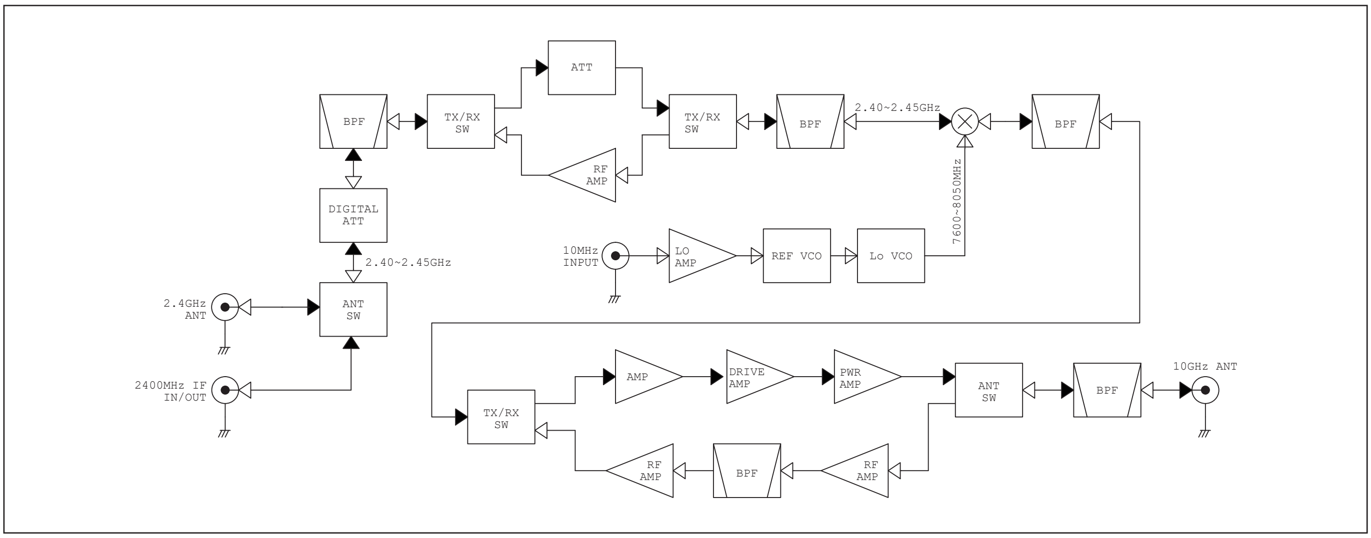

Figure 06-3. Block diagram of the CX-10G 10 GHz Transverter

As mentioned earlier, the IF signal supplied to the transverter is obtained from the RF unit of the IC-905. Therefore, it is easy to obtain a high-level IF signal. Since this high-level IF signal is mixed with the local oscillator signal, the RF signal can also be output at a high level. At the same time, however, the IF signal level increases not only the spurious component but also the distortion. Low and high harmonics in the spurious components can be removed by installing a BPF in the next stage of the mixer, but distortion and proximity spurious components in the target signal cannot be removed.

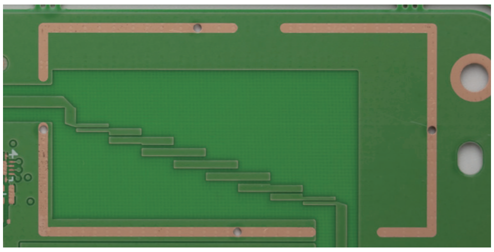

Figure 06-4. BPF installed in the next stage of mixer circuit

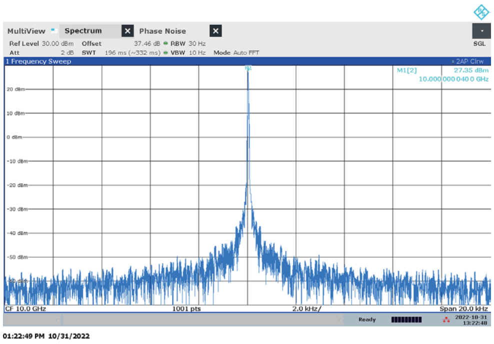

Figure 06-5. 10GHz signal spectrum
(Span:20 kHz/RBW:30 Hz/VBW:10 Hz)

Not limited to the IC-905, Icom's designs emphasize creating clean and highly stable signals. We stuck to a countermeasure against proximity spurious and distortion in 10 GHz RF signals, a digital attenuator with variable attenuation is used in addition to a conventional attenuator with fixed attenuation to adjust to the appropriate input level to the mixer. These attenuators also operate during reception to adjust to the appropriate level to the IC-905 when converting from the 10 GHz band to the 2.4 GHz band.

The IC-905 is also designed for easy operation in the 10 GHz band without the hassle of using a transverter, even when connected to a CX-10G transverter.

Figure 06-6. The BAND selection screen also displays a button to select the 10 GHz band

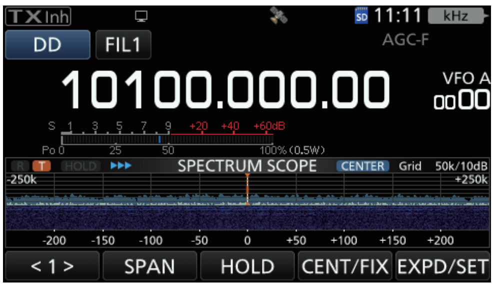

Figure 06-7. An example screen displaying the 10 GHz band (1).

When a transverter is connected and operated, the operating frequency must normally be calculated from the frequency displayed on the radio outputting the IF signal. However, with the IC-905 and CX-10G set, the IC-905 recognizes the connection of the CX-10G and displays the operating frequency in the 10 GHz band as it is, without recognizing that a transverter is connected and in operation. Similarly, the internal circuitry automatically switches the local oscillator signal frequency even in the wide bandwidth of 10 GHz. This makes it possible to scan multiple bands at once, from the 144 MHz band to the 10 GHz band, and enables seamless operation as if it were a single transceiver.

The connection between the CX-10G and the IC-905 consists of only three cables. One control cable, that doubles as a power cable, and one coaxial cable each for the IF signal and the 10 MHz reference signal. These three cables connect the CX-10G to the RF unit of the IC-905 mounted on the antenna mast, so no long cables are needed.

The CX-10G, like the RF unit of the IC-905 is mounted on the mast directly below the antenna using a special bracket. When using the optional AH-109PB (10 GHz band parabolic antenna), connect the bracket of the parabolic antenna to the bracket of the CX-10G and use the semi-rigid cable supplied with the parabolic antenna.

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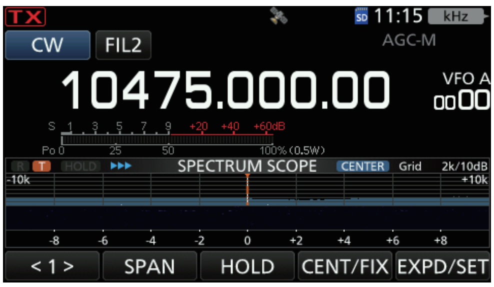

Figure 06-8. An example screen displaying the 10 GHz band (2).

Since 10 GHz signals are created using 2.4 GHz signals, it was explained earlier that the CX-10G (10 GHz Transverter) must be connected to the IC-905 RF unit. Therefore, the 2.4 GHz band antenna will be connected to the 10 GHz Transverter. When operating in the 2.4 GHz band, the antenna is automatically connected to the 2.4 GHz antenna through an antenna switching circuit inside the CX-10G, so there is no confusion in terms of operation.

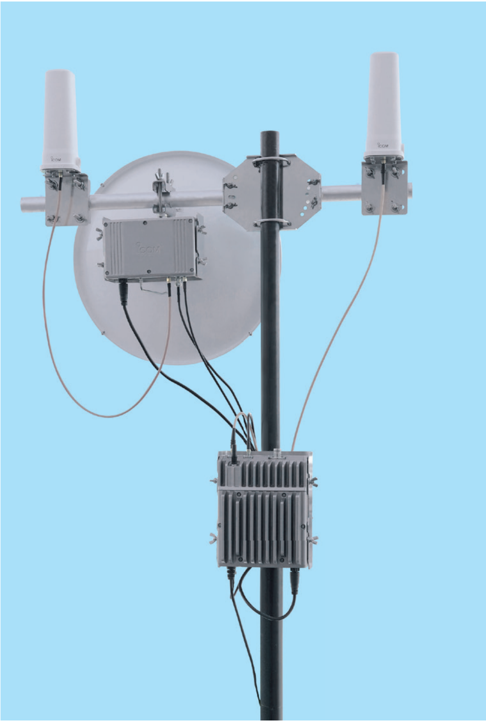

Figure 06-9. Connections example between the IC-905XG and its antennas.

If the IC-905 is used as the main unit, transverters in other bands can be connected simply by modifying the software related to transverter control. For this reason, we are focusing on communication in the 24 GHz band following the 10 GHz band. So far, we have repeatedly tested prototypes of 24 GHz band transverters and conducted communication experiments and have obtained good results so far. Through these experiments, we are conducting further research toward the practical application of general-purpose communication devices, not limited to amateur radio communications.

Thoughts on 24 GHz transverter development

The IC-905 itself is a 144 MHz to 5.6 GHz transceiver as explained earlier. It also supports 10 GHz by connecting to the CX-10G, 10 GHz Transverter. The 10 GHz signal is generated by mixing the 2400 MHz IF signal from the IC-905 with a 7600 MHz to 8050 MHz local oscillator signal generated by the CX-10G's internal PLL/VCO. This PLL/VCO has the feature that the oscillation frequency can be changed by programming. In other words, by selecting the appropriate IF signal frequency and local oscillation signal frequency and changing the program, it is possible to realize a 24 GHz band transverter that is further above 10 GHz.

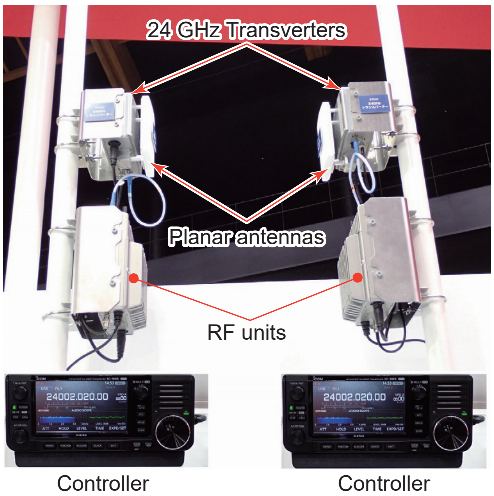

Figure 06-10. Prototype of the 24 GHz transverters.
(There are two identical transverters for TX and RX)

Based on these considerations, we have selected an IF signal in the 5600 MHz band and associated local oscillator signal and have developed a prototype 24 GHz band transverter. We are also conducting communication experiments as an accessory device for the IC-905 and have obtained good results. We may be able to publish these results in some form in the near future.

Prototype of the 10 GHz repeater

With the release of the IC-905, SHF band operation will become more accessible than ever, but there are still only a few stations we can communicate with. Although it is possible to communicate with stations in unexpected areas such as mountain diffraction, rain scatters, and reflections from buildings in the city. However, the SHF band is not sufficient in terms of propagation distance. To compensate for this, repeaters have been installed in the SHF band. According to the JARL repeater list as of December 1, 2024, there are four repeaters in the 5.6 GHz band and three in the 10.1 GHz band in Japan. All of them are FM repeaters, but the total number of stations is very small for 7 stations.

Therefore, in order to revitalize the SHF band, Icom decided to provide repeaters. However, it takes a considerable amount of time to design a repeater from scratch and provide it. We combined an existing ID-RP1200VD for a 1.2 GHz band D-STAR® repeater with two CX-10G, 10 GHz Transverter units, and configured them to be finished with minimal work by making circuit and software changes to shorten the developing time.

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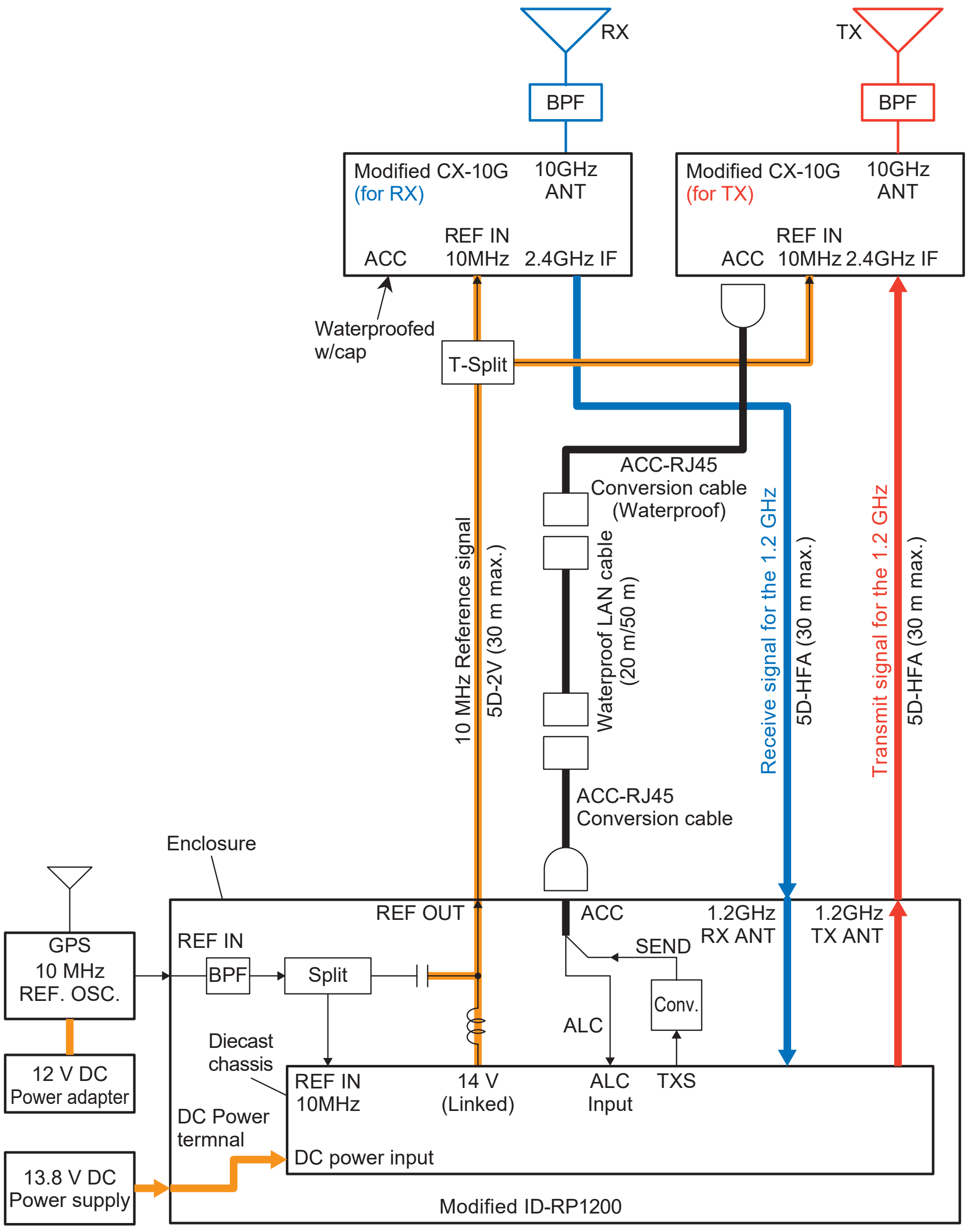

Figure 06-11. Configuration of the prototype 10 GHz repeater.

The reference frequency is supplied to the ID-RP1200VD (modified) and the CX-10G (modified) using a commercially available 10 MHz GPSDO oscillator. Since the IF frequency was changed from the 2400 MHz band to the 1200 MHz band, the center frequency of the BPF for IF and the local oscillator frequency of the CX-10G were changed. Other than these, the CX-10G is almost the same as the CX-10G.

Figure 06-12. Receiving 10 GHz signal from the JR3VE D-STAR® repeater.

The CX-10G (modified) is installed directly under the antenna to minimize loss in the coaxial cable, just like the original CX-10G, and the ID-RP1200VD (modified) is installed inside the station building (Repeater site).

The following cables are required to connect the ID-RP1200VD (modified) and CX-10G (modified).

➥ Two coaxial cables for IF signals (for transmitting IF and receiving IF).
➥ One cable for transmission control.
➥ One coaxial cable for reference frequency signal for transmitting and receiving of the CX-10G (modified).

The power supply for the CX-10G (modified) is supplied superimposed on the coaxial cable for reference frequency signal.

The original ID-RP1200VD is a repeater that supports both D-STAR® (DV/DD mode) and FM mode, but the 10 GHz repeater currently being prototyped has been applied for as a DV mode repeater by JARL (Japan Amateur Radio League). It began operation as JR3VE at Icom Head office in Osaka on February 5, 2025. By using it as a DV mode repeater, further communication possibilities are expanded, such as connecting to a D-STAR® gateway and communicating via a network. It can also be used as a means of communication in emergencies such as natural disasters.

Figure 06-13. Accessing to the JR3VE 10 GHz Repeater.

We plan to continue installing this 10 GHz repeater on the rooftops of buildings in urban areas. If it can be installed on a mountaintop or the rooftop of a high-rise building with a good view, we think it will be easier to access it with the IC-905 connected to the 10 GHz transverter.

Figure 06-14. Prototype of the 10 GHz Repeater

Designing of antenna and filter for the SHF band

As we proceeded with the design of the IC-905 as an SHF transceiver, the antennas and BPFs designed for SHF could be evaluated using measuring equipment, but evaluation in actual operation was also necessary.

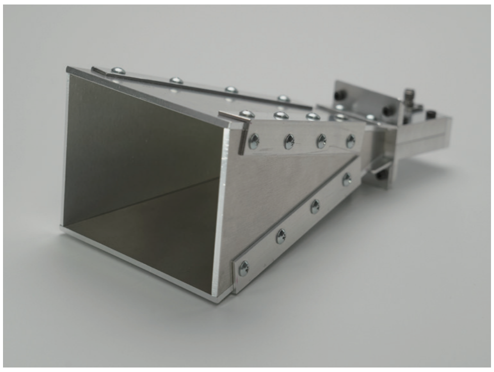

Figure 06-15. Prototype of the 10GHz band Horn antenna

At Icom, we design and manufacture wireless network equipment, so the 2.4 GHz and 5.6 GHz LAN antennas can easily be diverted for amateur operation. However, for the 10 GHz band, there was only a parabolic antenna for the D-STAR® assist repeater in our product line, but there were no other antenna options. Parabolic antennas have a sharp directivity and high gain, but the disadvantage is that communication becomes impossible if the antenna direction is changed even slightly. For this reason, we thought that omni-directional antennas were also necessary to make operation easier, and prototyped colinear and biconical antennas. However, in actual operation, the gain was still insufficient compared to the parabolic antenna. For this reason, we have created a prototype horn antenna as an intermediate antenna between a parabolic antenna and an omni-directional antenna. We have created prototype horn antennas for the 5.6 GHz and 10 GHz bands, and after testing, we have concluded that both are practical antennas in terms of size, gain, and directivity.

The prototype horn antenna was created in-house, with repeated paper design and prior evaluation of characteristics using a simulator, and since certain results were obtained, the material processing and assembly were done using machine tools. In addition to this horn antenna, we have also designed and prototyped a BPF (Bandpass Filter) for the 10 GHz and 24 GHz bands using a cavity resonator, and obtained the good characteristics shown in Figure 06-17 and Figure 06-18. This was exhibited for reference at the 2023 Ham Fair held in Tokyo and other events.

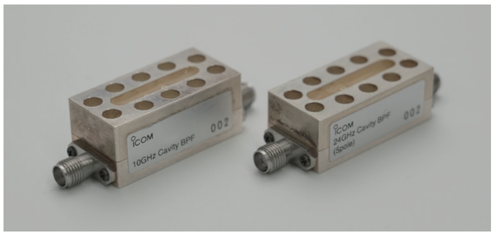

Figure 06-16. Prototype of the BPF

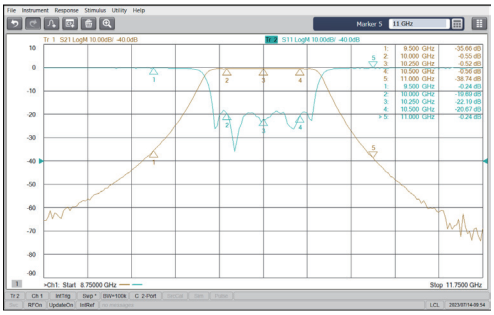

Figure 06-17. Characteristics of the 10 GHz BPF

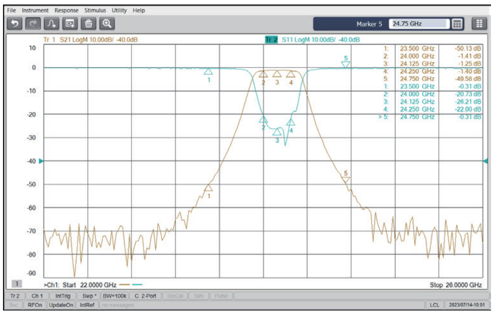

Figure 06-18. Characteristics of the 24 GHz BPF

Market Response 07

~IC-905: A game changer in microwave operation~

JA7JJN, Yanagisawa Hideo

A single LAN cable connects the Controller in the shack to the RF unit on the tower, allowing operation in all modes from 144MHz to 10GHz! Who could have imagined something like this when I first entered the microwave world in the early 2000s? At the time, the general style of fixed microwave operation was to connect the master radio (VHF/UHF transceiver) in the shack to the transverters for each band installed on the tower with multiple coaxial cables. Moreover, the frequency was unstable, and the beam direction was not accurately aligned, so communication was often not possible. However, now that the IC-905 has been released, the frequency has become dramatically stable, and the band status is clear at a glance with the spectrum scope on the display. I think it is no exaggeration to say that the common sense of microwave operation has been fundamentally changed.

Moreover, it is also expected to be expandable. If you set the 144 MHz, 430 MHz, and 1200 MHz of the IC-905 to IF frequencies, you can operate a 24 GHz transverter without adding additional coaxial cables. If I had to mention one challenge, it would be to make it even smaller and lighter.

Portable operation is common for the microwave operation among amateurs. You can enjoy long-distance communications by climbing a mountain. For this, it is advantageous to have a small and light rig. Technology is constantly evolving. I dream of a time when we will be able to enjoy QSOs from the top of Mt. Fuji with a handheld microwave transceiver.

Figure 07-1. JA7JJN, Mr. Yanagisawa in operation

Figure 07-2. Interaction with JA1OGZ, Mr. Kaneko (Right)

Profile of JA7JJN, Yanagisawa Hideo

Born in Fukushima Japan, he joined Japan Broadcasting Corporation (NHK) in 1977. Starting at NHK's Yokohama Broadcasting Station, he served as an NHK's overseas correspondent and Cairo Bureau Chief from 1984. He is currently a freelance journalist. He has been interested in electrical and mechanical engineering since his boyhood. He is also an amateur radio operator, and his call sign is JA7JJN. He is especially interested in microwave communications, and in mid-November 2014 he set a communication record of 225 kilometers on 77 GHz. Because he is an amateur radio operator, he was also able to interview King Hussein I of Jordan, whose call sign was JY1.

~IC-905XG User Report~

JA1OGZ, Kaneko Akira

Introduction

It has been about a year and a half since I bought the IC-905. At first, I used it for portable use and for 6 m AND DOWN contests, including FM-TV. Currently, I am using it installed on a tower.
A portable station using the same IC-905 transmits videos of the operating location to me through FM-ATV, and I also transmit it to the station, so I enjoy both. It can be operated in various modes, but I have not really used it much. It was the first microwave radio to meet the technical standards compliance certification, and I think it was an extraordinary effort by the company to lead the development and production of various laws and regulations and bring it to market. For those who are trying microwaves for the first time, even if you start from scratch the finish level is something that you cannot get at this price. Even veterans who have already built microwave radios themselves will be fascinated by the frequency accuracy and ease of use. I would like to write about the following points that I feel in particular when using the IC-905.

Figure 07-3. JA1OGZ, Kaneko Akira operating

AFC (Automatic Frequency Control) Function

When operating microwave using FM, the transmitting frequency of each station can be slightly different. The AFC function makes it easy to track the frequency of the other station, so I always keep AFC ON. In particular, when I moved to the mountains during the 6 m AND DOWN contest and was on the receiving end, the other station's frequency was slightly off, but it instantly tuned in, and I was able to clearly hear the other station's call sign. The AFC function is very useful when many stations are participating, such as in a contest. Recently, many stations operating microwaves lock their oscillators with PLL, but there are still many radios that use local oscillators that only multiply a crystal, so this function which instantly tracks frequency differences is very useful.

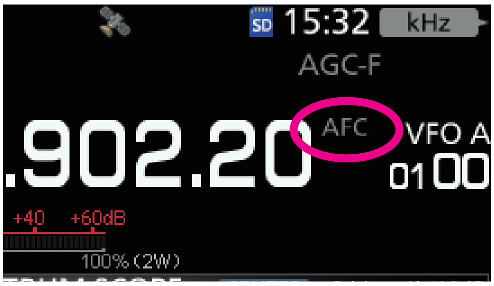

Figure 07-4. Screen appearance when AFC is ON

The entire bandwidth can be operated

When a homemade or manufacturer's transverter is connected to a VHF or UHF radio as the master unit, and operated on SHF frequencies, the maximum bandwidth that could be transmitted and received are limited to the operating range of the master unit's radio. For example, if a 5.6 GHz transverter is connected to a 1.2 GHz master unit, even though the 5.6 GHz bandwidth is 200 MHz, the actual operational frequency width is only 40 MHz of the 1.2 GHz bandwidth. Furthermore, if the master unit is a 430 MHz transceiver, the bandwidth becomes even narrower, at 10 MHz. The IC-905 can transmit and receive over the entire bandwidth permitted for amateur radio eliminating these previous restrictions.

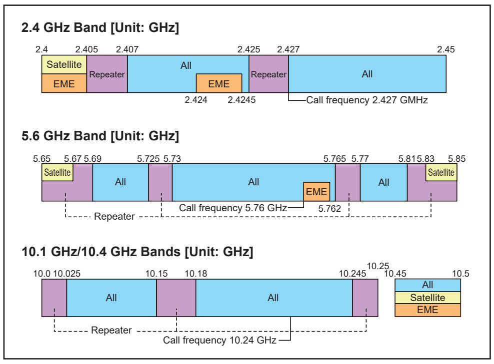

Figure 07-5. Band plan of 2.4~10 GHz for Japan's amateur radio

On the other hand, my homemade 5.6GHz/10.1GHz transverter cannot receive amateur satellite signals at 5.84 GHz because of the bandwidth of the master unit. To solve this problem, I have installed two local oscillators for different frequencies in a conventional transverter, switched the oscillators with a relay, and connected each signal to a mixer to switch between the upper and lower bands. I have set up this relay to switch from the shack. Similarly, for the 10GHz band, I have set up two local oscillators with different frequencies in the transverter so that both the 10.1GHz and 10.45GHz bands can be used, and these are also switched from the shack. I have adjusted the internal BPF (Bandpass Filter) characteristics so that the 10.24GHz and 10.45GHz bands pass through, suppressing the center frequency characteristic of 10.36GHz, and adjusting the BPF characteristics so that the characteristics are exactly M-shaped. I have also taken great pains to place the local oscillators on the lower and upper sides of the BPF. Since switching to the IC-905, I have been able to use it continuously, which has freed me from that troublesome system. And when actually receiving the 5.84 GHz signal from the satellite, the frequency changes rapidly from about +120 kHz to –120 kHz over a 10 minute period due to Doppler frequency shift, so I control the frequency using the CI-V connected via a USB cable.

In the 2400MHz band, it is possible to receive frequencies from 2300MHz to 2450MHz, which are still available for amateur radio stations overseas. Particularly, 2395 MHz is used for the digital amateur TV frequency of the International Space Station (ISS). This digital amateur TV system is the DVB-S system, so the IC-905 will not produce an image, but it should be possible to capture the carrier when DVB-S video with a bandwidth of about 2 MHz is broadcast from the ISS.

Use for EME communications

The 10GHz band is designed to receive continuously from 10.0 GHz to 10.5 GHz, so it seems like it is possible to challenge EME communications. The fact that it can also receive 10.368 GHz is good news for those aiming for EME. Reception is at 10.368 GHz, but transmission from Japan is at 10.45 GHz. A low NF (Noise Figure) and LNA (Low Noise Amplifier) are required for reception. Of course, an output of about 20 W is required for transmission, but the fact that 10.368 GHz and 10.45 GHz split operation can be used for transmission and reception makes it possible to challenge immediately in terms of creating an EME system. I have heard a heartbreaking story of a Japanese amateur station making a receiving converter that can receive 10.45 GHz and sending it to an overseas station because overseas stations have to receive at 10.45 GHz. If overseas EME stations start using the IC-905XG, it will be possible to freely operate split.

Use the IC-905XG for geostationary satellite QO-100

The Es'hail 2 TV broadcasting satellite launched by Qatar in the Middle East also carries a repeater for amateur radio. While this satellite was being built at Mitsubishi Electric's Kamakura factory, AMSAT-DL came to Japan several times to finalize the design specifications. Unfortunately, it is not accessible from Japan because it is stationary at 26 degrees east longitude, but it can be used from Indonesia and Thailand. The amateur radio repeater for this satellite can be used for 2.4 GHz uplink and 10.48 GHz downlink.

Since it is difficult to install a feed horn directly to the CX-10G, a 10.48 GHz LNA (Low Noise Amplifier) is installed between the feed horn and the CX-10G, and then get extra RF gain with a low NF. This is a necessary condition to cover the loss of the 10 GHz coaxial cable. Depending on the operating location, the distance to the QO-100, and the size of the parabolic antenna, it may be necessary to attach a 2.4 GHz 2 to 3 W amplifier.

When will Artemis' manned lunar space station begin communication?

A space station orbiting the moon is being planned. Currently, the International Space Station (ISS) uses the 144 MHz and 430 MHz bands as part of its amateur radio service. In the future, manned airships orbiting the moon are planned to use 5.6 GHz for uplink and 10.45 GHz for downlink. Looking at the frequency combination, the IC-905XG covers these frequencies, so although it may be necessary to increase the size of the antenna and the transmission power of 5.6 GHz, communication with manned spaceships may become a reality. I cannot wait for things to move forward in more detail.

How does the CX-10G handle frequency control to cover the entire wide bandwidth?

Just out of curiosity, I wondered how the IC-905's IF frequency of 2.4 to 2.45 GHz is controlled over the 500 MHz band from 10 GHz to 10.5 GHz. I extracted a signal from the 2.4 GHz IF and checked the frequency change, and it seemed that the 10 GHz local oscillator inside the CX-10G stepped up when it went up to 2450 MHz and then back to 2400 MHz. The frequency control on the CX-10G side seemed to send frequency information to the PLL/VCO through the ACC cable. The CX-10G is itself a 10 GHz transverter with an IF of 2.4 GHz and cleverly changed the frequency of the transverter's local oscillator so that the entire bandwidth can be used without interruption.

Figure 07-6. JA1OGZ, Mr. Kaneko's radio shack

How is the receiver sensitivity?

A station using the IC-905 asked me the question, "Why is the S meter not moving well?" Many homemade units have many RF amplifier stages installed in the transverter, and in many cases an amplifier is also inserted in the IF stage. When I connect the master unit to the transverter and see that the S-meter is moving up to about S9 without connecting an antenna, I can see that the transverter is working, so I can feel relieved. Naturally, when I receive a signal from the other station, the S-meter will show as 59++ full scale.

(Continued on the next page…)

So, what is the reception sensitivity of the IC-905? Most of the reception sensitivity notations in the instruction manual are written as the input signal level at which the S/N ratio is 10 dB when receiving in SSB. The input signal level at which the SINAD is 12 dB when receiving in FM. For VHF/UHF receivers, a S/N ratio of 10 dB in SSB is –126 dBm (–19 dBμV) and we can say this is good sensitivity. When I measured it, it was the same as the sensitivity of other VHF/UHF receivers. The sensitivity is also expressed as MDS (Minimum Discernible Signal). A standard signal generator is connected to the antenna terminal and a signal with a level lower than –140 dBm is connected. The signal level is evaluated at a level where the beat sound is 3 dB higher than the noise level at 500 Hz CW filter. These values were also –136 dBm to –139 dBm, so the sensitivity was not poor. On the other hand, the S-meter swing was about –93 dBm (+14 dBμV), which was almost the same as the other IC-705 settings in the 430 MHz band or was set to swing by a few dB. In addition, when checking the S-meter swing and receive sensitivity for +20, +40, and +60 dB over S9 with a standard signal generator, it was possible to read those values.

By changing the antenna of the other station, you can compare the S-meter sensitivity and the receiving sensitivity. Another reason why the S-meter sensitivity is not so good is that the phase noise of the IC-905's local oscillator is lower than -100 dBc/Hz at 10 kHz offset, which may explain why the S-meter does not move even when the antenna is not connected. Many amateur radio stations that operate microwaves use parabolic antennas, so if the antenna gain is 25 dBi to 30 dBi, it can amplify weak signals by about 300 to 1000 times and supply them to the radio. In this way, antenna gain is an important factor in microwave communications and supports them.

Real-time spectrum scope is a powerful tool for microwave

To find a weak signal from a DX station, the receiving station change mode in SSB or CW and the faint beat sound used to fine-adjust the frequency and direction of the antenna. This takes up most of the time. Over the past 10 years, the frequency has been controlled by OCXO (Oven Controlled X'tal* Oscillator), which has made the frequency more accurate and stable. After that, the influence of the antenna direction and the radio wave propagation conditions on the day are important factors for microwave communications.

*X'tal=Crystal

Even in the days before an OCXO was installed, there was a very famous amateur radio OM who always found the DX station even though these operations took time. The IC-905 is equipped with a real-time spectrum scope and has an accurate frequency, so it is now possible to tune the frequency and parabolic antenna direction of the DX station by chasing the faint bright lines that appear in the waterfall screen. In other words, if a bright line does not appear on the spectrum scope, you may easily give up trying to find a DX station, thinking that there is no station. The beam width of a parabolic antenna is very sharp, so it is difficult to find a DX station unless the direction is within a range of about 20 to 30 degrees. Also, if the antenna is not swung widely enough, communication may occur through the sub lobe not the main lobe of the parabolic antenna.

The Japan's Radio Law states that, among the operating frequencies of amateur radio stations, "amateur radio operations are secondary operations from 1.2 GHz to 10.1 GHz, and when using these frequencies, it is necessary to confirm by documents that appropriate measures can be taken to avoid causing harmful interference to primary operation radio stations." Bandwidth of the spectrum scope is up to 50 MHz, so you can easily watch the signals of other stations and visually check whether there is any signal in the band. In the 2.4 GHz and 5.6 GHz bands, the IC-905 is equipped with a carrier sense function which further ensures that interference with primary operation radio equipment can be avoided.

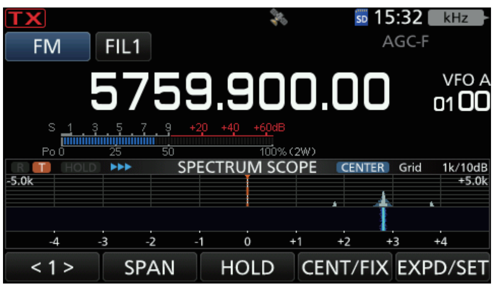

Figure 07-7. The screen showing a signal about 2.8 kHz away

FT8 Operations

Previously, some people were using 1.2 GHz and 5.6 GHz microwaves to communicate over distances of 185 km in JT65C mode. The frequency stability of the radio equipment including the master unit of IC-910 was frequency controlled based on a 10 MHz frequency generated by GPS. Some groups use IC-905 mainly for FT8 which is used in the HF band, so I think it will enable communication over longer distances via rain scatter during the rainy season and abnormal propagation via ducts. We hope that pioneers will work to make it possible for people in distant areas to communicate using FT8 similar to the microwave beacons.

Summary

I started writing this as a user report for the IC-905, but as I learned more about the differences between the IC-905 and a microwave radio made by connecting a VHF/UHF radio to a homemade transverter, I became interested in knowing the performance of this radio. As an amateur, I have written down the test result values I got from my own uncalibrated measuring equipment, but please consider it as a reference only.

My impression is that the IC-905 is very compact and well-packaged for a radio that can transmit and receive from 144MHz to 10.45 GHz. Conventionally, the transverter was installed on top of the tower, and multiple coaxial cables, power cables, and PTT control cables were laid from the shack to the antenna tower for the number of operating bands. I think the manufacturer probably thought that it would be difficult to optimize the power supply to the master unit and transverter because the cable length differs depending on the installation location. To solve this problem at once, they installed all the RF units on the antenna tower and connected them with LAN cable which is a reasonable configuration method. In addition, the length of the DC power cable differs from user to user, and I was surprised to see that a DC power supply method was adopted that converts the power to high voltage using PoE++ (Power over Ethernet) and suppresses the current in order to supply the appropriate voltage to each element of the RF unit. I also wonder how they can achieve this without any variation in transmission power over such a wide band.

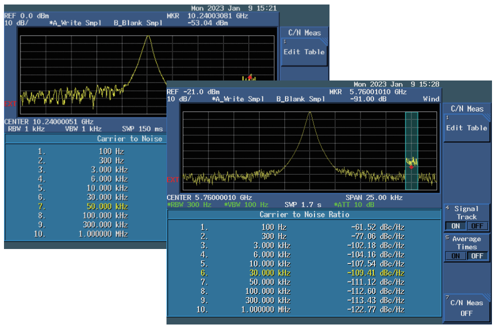

Figure 07-8. An example of measurement results

Figure 07-9. Portable operation using the IC-905

The radio wave types that can be used are not only FM but also CW/SSB/AM/RTTY, FM-ATV, and even FT8, so it seems that you can use it in a way that suits you. The IC-905 has extremely lowered the hurdle for radio operators who are trying out the microwave band. Thanks to it, anyone can now get involved. One thing to be careful of is that many microwave bands are shared with other wireless equipment, so I would like to operate with care to avoid interference and enjoy new encounters with microwaves.

Profile of JA1OGZ, Kaneko Akira

He got his amateur radio station call sign in 1963. From 1980, he became interested in communications using low orbit satellites and operated through them every night after returning home from work. In 2000, he became interested in microwave communications especially when large amateur satellites began carrying microwave transponders. Since 2000, he has built and operated transverters from 5.6 GHz to 77 GHz. He is a member of the board of directors of the Japan Amateur Satellite Association (JAMSAT), and is supporting universities and other organizations that plan to install 5.8 GHz transmitters on amateur satellites.

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