Anritsu Advancing beyond

IQ Streaming with Anritsu's Field Master Pro™ Real-Time Spectrum Analyzer

Introduction

In a world of increasingly sophisticated wireless signals competing in the available spectrum, the ability to capture and analyze those signals is in greater demand than ever. Interference — both unintentional and nefarious — threatens the fidelity of communications systems in high frequency (HF) and all the way up to millimeter-wave (mmWave) frequencies. With the Field Master Pro™ MS2090A Real-Time Spectrum Analyzer, Anritsu is now opening new doors for signal capture and analysis out in the field that have previously been restricted to the lab.

The Field Master Pro offers premium performance in three critical areas for spectrum intelligence:

1. **Frequency Coverage:** with full coverage up to 54 GHz, there are no gaps where signals can be missed.
2. **Bandwidth:** 110 MHz of capture bandwidth means more information across more spectrum.
3. **Real-Time Performance:** with a minimum detectable signal of 5 ns, even the shortest duration signals cannot hide from detection.

The Field Master Pro combines these key features to offer comprehensive options for IQ data capture and streaming. Analysis of IQ data has become the most important tool in the signal analysis tool box. Using standard software applications, every detail of an RF signal can be analyzed and categorized. The Field Master Pro provides a unique combination of high RF performance in a field portable spectrum analyzer that can stream wide bandwidths of IQ data continuously.

This application note will describe the Field Master Pro IQ streaming options and how to set them up to optimize for any application. Once IQ data has been recorded, it can be post processed in a number of PC applications including MATLAB, X-COM Spectro-X, and Anritsu MX280005A Vector Signal Analysis software.

Streaming IQ Data with the Field Master Pro MS2090A

What is IQ Streaming?

When a signal analyzer, like the Field Master Pro, processes RF signals, it captures portions of RF energy (up to 110 MHz of bandwidth) hundreds of thousands of times a second then processes that data into the frequency domain using a Fast Fourier Transform (FFT). That allows the analyzer to translate the information into the graphic displays of spectrum that are typically associated with the instruments. In some cases, however, users may want to take that raw sampled data — before it is converted to the frequency domain — and break it down into the I and Q parts for deeper analysis. This enables greater insights into the signal, like the checking modulation quality, slowing the playback of the signal to see changes over fractions of time — down to nano seconds of time resolution — or analyzing other signal characteristics that can help identify and track the signal. IQ streaming is simply the ability of the analyzer to take that data before it is processed and store it to an external device for later processing.

IQ streaming differs from IQ capture in that the recording of IQ data is not limited in time, other than by the available memory in the recording device. IQ capture is typically used for the capture of short bursts of IQ data into the signal analyzers internal memory. It is then exported to an external PC for later post processing. IQ streaming from a signal analyzer utilizes one of the analyzer ports to continuously stream IQ data to an external device. The Field Master Pro has Ethernet, USB 3.0, high speed data and PCIe ports that can be used for IQ streaming, each has its own merits as will be

Setting Up the Stream Parameters

To set up the Field Master Pro for IQ streaming, go to the MEASURE menu from either the spectrum analyzer or RTSA mode (see Figure 1 for reference). Find the CAPTURE MODE drop down selection and select "Streaming". In streaming mode, the analyzer has several options for configuring the data stream, as laid out in the next several sections.

Capture Bandwidth and Sample Rate
The capture bandwidth and sample rate are tied together to determine 1) the frequency span of the capture from the center frequency, and 2) the rate at which the analyzer samples the IQ data (see Figure 2). The Field Master Pro offers up to 110 MHz of capture bandwidth at 200 MS/s (option dependent), but more bandwidth is not always desirable. More bandwidth and faster sample rates means more data that must be stored into memory and poured over in post-processing. 110 MHz streams will fill up storage much faster than a 1 MHz capture bandwidth. The key is to select as narrow a bandwidth as possible for a particular application. A regulator doing spectrum monitoring may want to see spectrum activity on as wide a span as possible, whereas a radar transmitter may only care about kilohertz worth of spectrum where their signal resides. Setting the right bandwidth will make later processing much easier.
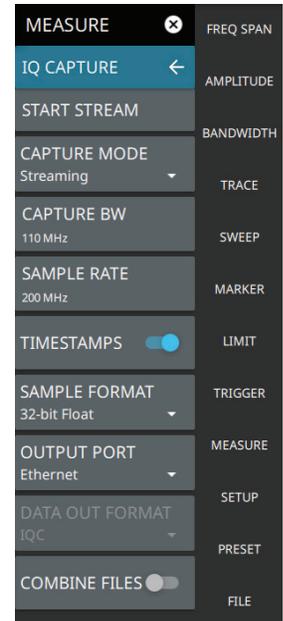
*Figure 1.
Field Master Pro
IQ Capture
Setup Menu*

Figure 2. Capture Bandwidth and Sample Rate Selection

Timestamp

Users can also choose whether or not to capture a timestamp with each IQ sample. This enables precise correlation between the time and any spectral phenomena. The trade off, however, is that the timestamp takes up bits within the capture, so the user has to either give up some resolution in the capture (the result being a rise in the noise floor of the playback) or capture a greater bit depth. The greater bit depth might help offset the loss in resolution of the signal, but more bits captured will equal more data and will fill up memory faster.

Sample Format (Bit Depth)

Given unlimited bit depth and sample rate, an IQ capture can perfectly recreate an RF signal from any period in time. In the real world, however, more bit depth and more samples come at a cost of more bits, and these bits can quickly consume gigabytes of storage and tens of gigabits per second of streaming bandwidth. Every capture contains noise. At some point, more bits only serve to better quantify the noise and no longer provide any additional insight into the signal. For more information on how to select a proper bit depth for a given situation, see the Anritsu White Paper "Choosing the Best Bit Depth for IQ Captures or Streams", available for download on Anritsu.com.

Selecting a Storage Location for the Stream

The Field Master Pro offers several options for devices to which the data can be streamed. As discussed, there are many possible applications that require IQ data analysis, and different use cases will have different requirements. Some cases might call for huge amounts of data to be stored and analyzed at a time. For other applications, portability may be the most important factor. Choosing the right device will depend greatly on the application.

One important consideration is the possible trade-off between capture bandwidth and gaps in the IQ data. Think of the data like water flowing through pipes. Different storage devices have different size pipes and will thus support the transfer of different amounts of data. When more data is coming in than can be pushed out, gaps will occur in the final IQ file. Streaming the data without gaps requires fast enough transfer speeds to get the data out of the MS2090A RAM and into the target storage device. As the data is sampled, the Field Master Pro MS2090A stores it in a buffer in RAM, moves it to the storage device, and clears the data from the RAM as fast as possible. When the pipe between the instrument and the storage device is too narrow and the buffer fills up, the only solution is to stop filling the buffer and start dropping data. This dropped data causes gaps in the final IQ. In some cases, gaps may not be a critical issue, but in situations where every sample is needed to evaluate the signals, gaps could be the difference between success and failure in testing. The Field Master Pro monitors the stream and will give a message in the status bar if samples are dropped due to a lack of transfer speed: "Device transfer speed insufficient for gapless transfer at current BW/bit depth settings; some samples will be missed." As shown in Figure 3.
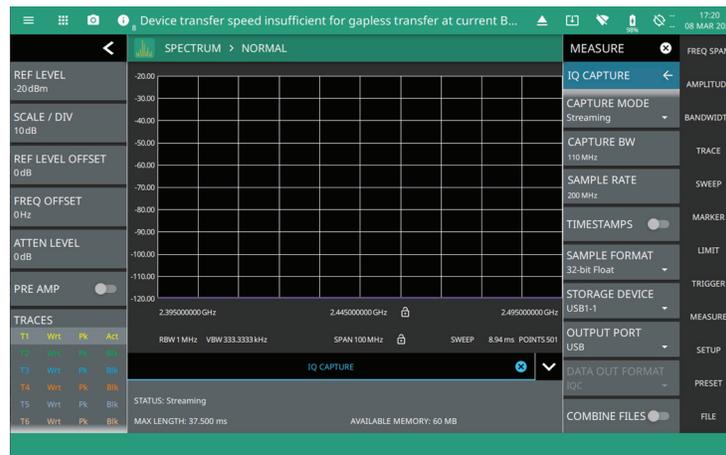
*Figure 3. Status Notification When Transfer Rate is Too Slow
and Gaps in the Data May Appear*

It is also important to consider the amount of data needed to be captured for analysis. As stated earlier, wider bandwidths or higher bit resolution will greatly impact the amount of data to be stored — as, of course, will the amount of time of the data stream. Table 1 shows the maximum time for which IQ data can be saved to a 1 TB drive for different combinations of bit depth and capture bandwidth. Select a storage device large enough to hold the amount of data you expect to capture.

Table 1. Hours of IQ Data That Can be Recorded to 1 TB of Storage at
Different Bit Depths and Capture Bandwidths

Bit Depth	Capture Bandwidth (MHz)			
	110	50	5	0.28
8	0.75 hr	2.43	23.86	3314.02
16	0.37	1.21	11.93	1657.01
32	0.19	0.61	5.97	828.50

The Field Master Pro offers a great deal of flexibility in choosing a device onto which the data will be streamed. IQ data can be streamed to USB 3.0 storage devices, PC via PCIe, PC via Ethernet, or X-COM's IQC5000B RF Record and Playback System. Some options are more portable, but have limitations in the amount of data that can be streamed. Others offer very wide bandwidth streaming, but require extra equipment and/or cost. Table 2 shows each of the options with special considerations and is followed by more detailed explanations in the next several sections.

Table 2. The Field Master Pro Offers Several Options for Devices
to Which IQ Data Can be Streamed

Capture Bandwidth (MHz)		
Streaming Device	Advantages	Other Considerations
USB 3.0 Storage Device	• Small/portable size • Inexpensive and easy to source • No special software required	• Requires special formatting for best performance • Limited gapless transfer rates
PC Over PCIe	• Full bandwidth streaming • Still affordable and easy to source • Supported by free MX280005A software	• Requires a PC that can host a PCIe interface card, typically a small desktop tower PC • Transfer link can be impacted by other PC processes • Requires MA25101A PCIe kit for PC • PC must be within 2 feet (~.6 meters) of instrument
PC Over Ethernet	• Easy to set up and control • No special hardware required, standard Laptop PC is suitable	• Most limited bandwidth/transfer rates
X-COM IQC5000B	• Up to 14 TB of storage, integrates with X-COM Spectro-X IQ analysis software	• Streaming fixed at 16 bit. Requires the MA25424A converter kit

USB 3.0 Storage Devices

Streaming directly to a USB device is perhaps the most convenient and cost-effective option offered by the Field Master Pro. USB storage devices are readily available through many commercial retail markets and the cost per byte continues to drop, while the total storage continues to grow — especially solid state drives (SSD). The main limitations with streaming IQ data to a USB storage device are the maximum achievable transfer speeds and the total size of storage.

A few tips for steaming to a USB device:

- SSD devices provide the fastest transfer speeds and should generally be used instead of hard disc drives (HDD).

- Formatting the drive to ext4 will improve the transfer speed from the Field Master Pro, but ext4 is designed for Linux operating systems. There are many free or paid PC applications available for download to handle the formatting. This can, however, make it more difficult to extract the data later on a Windows PC. Another application may be required to enable reading of Linux formatted drives.

- The overall size — or amount of storage — on a device will typically not have an impact on the speed of the transfers, so the bigger the better, especially for wider bandwidth captures.

- An SSD drive will provide a transfer speed of about 250 MB/s (when formatted to ext4). Table 2 (when formatted to ext4) shows the transfer speeds required for gapless streaming to any device with specific bit resolution and bandwidth combinations. As a side note, some USB 3.0 devices will advertise a transfer speed specification much higher than 250 MB/s, but this is usually achieved in very specific circumstances that are very different from IQ data streaming.

- The amount of data coming from the analyzer and being passed to the USB device is more than can be managed in a single file, so the streams are broken up into smaller files and transferred in batches to the USB drive. At the end of the stream, the user has the option to immediately and automatically combine the smaller files into one large file of IQ data. This is usually the most convenient option, but it can add a large amount of time at the end of the stream (time depending on the length and bandwidth of the stream). In situations where another stream needs to be started shortly after another has ended, waiting for the analyzer to complete the combining process may not be acceptable. These cases, the user can turn off the COMBINE FILES toggle. In this case, the end result of the stream will be one folder will one meta data file and many small IQ files. The Field Master Pro then offers an IQ Streaming Tool to combine the files at a later time.

To access the tool:

1. Open the system menu

2. Go to the TOOLS menu

3. Select IQ STREAMING

4. Press the IQ METADATA FILE button and select the meta data file (.dgzm) from the stream you'd like to combine (note that all the IQ files and the meta data file will be stored in the same folder and must stay in the same folder for combination)
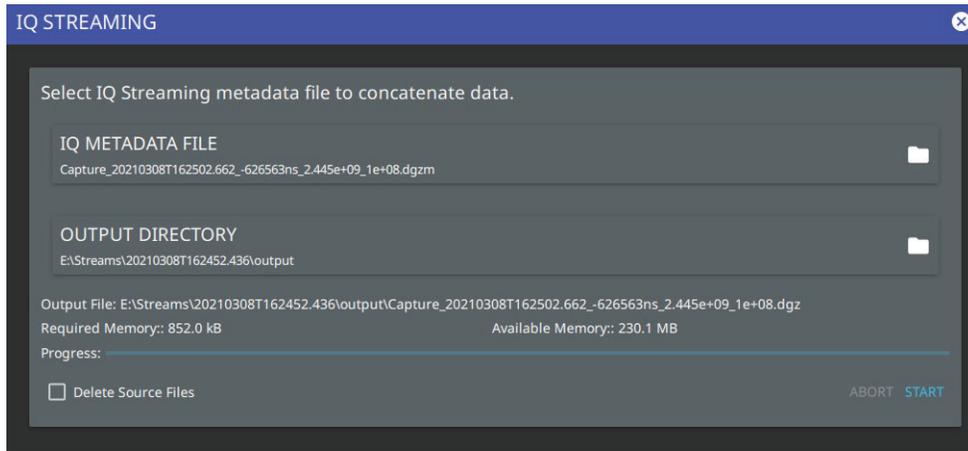
5. Press the START button. When the combination is complete, a system notification will verify the success of the combination.
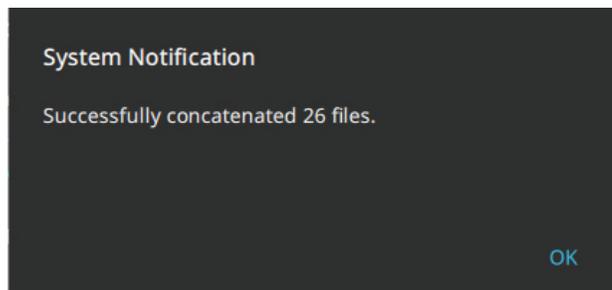
*Table 3. Transfer Speeds Required for Gapless IQ Data Streaming
from a Field Master Pro MS2090A*

Output I/Q Rate MSPS	Usable Bandwidth (MHz)	I/Q Bit Depth			
		32	16	10	8
200	110	1600.00	800.00	500.00	400.00
122.88	100	983.04	491.52	307.20	245.76
100	80	800.00	400.00	250.00	200.00
92.16	74	737.28	368.64	230.40	184.32
61.44	50	491.52	245.76	153.60	122.88
50	40	400.00	200.00	125.00	100.00
46.08	36	368.64	184.32	115.20	92.16
30.72	25	245.76	122.88	76.80	61.44
25	20	20.00	100.00	62.50	50.00
23.04	18	184.32	92.16	57.60	46.08
15.36	12	122.88	61.44	38.40	30.72
12.5	10	100.00	50.00	31.25	25.00
7.68	6	61.44	30.72	19.20	15.36
6.25	5	50.00	25.00	15.63	12.50
3.84	3	30.72	15.36	9.60	7.68
3.125	2.5	25.00	12.50	7.81	6.25
1.92	1.5	15.36	7.68	4.80	3.84
1.5625	1.25	12.50	6.25	3.91	3.13
0.36	0.28	2.88	1.44	0.90	0.72
0.045	0.036	0.36	0.18	0.11	0.09

To set up a stream to a USB storage device, select USB from the OUTPUT PORT selection, then in STORAGE DEVICE select the name of the device to which you want to stream.

STORAGE DEVICE
USB1-1 ▾

OUTPUT PORT
USB ▾
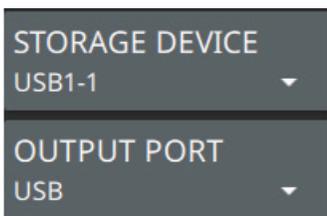
PCIe and Ethernet to a PC

The Field Master Pro also supports streaming directly to a PC over a PCIe or Ethernet interface. The PCIe option is the highest performance option, in terms of size, cost, and the amount of bandwidth and bit resolution that can be streamed without gaps — a full 800 MB/s, which supports 110 MHz of data at 16 bit resolution. Ethernet, on the other hand, is one of the more convenient options because it does not require any special hardware and data does not need to be transferred from one device to another for post-processing.

Unlike streaming to a USB device, which pushes the data to storage, streaming to a PC is more of a pull of the data from the instrument to the PC. Doing the data pull, however, requires special management of the data on the PC side. To assist in this process, Anritsu provides the MX280005A IQ Signal Master. This is a free, downloadable software with controls to connect to an instrument, set up the streaming parameters, start/stop the stream, and save the data to local storage. It also monitors the stream and gives detailed information on any gaps in data that arise from a loss in transfer speeds.
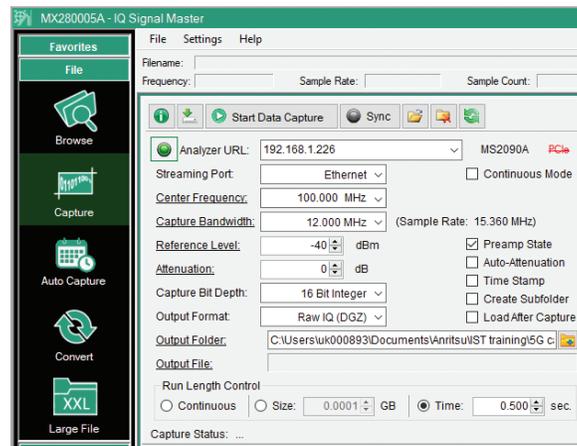
Figure 4. Anritsu's IQ Signal Master Application MX280005A for Configuring and Controlling Streaming to a PC or USB Drive

As with streaming to a USB device, a major consideration here is the transfer speed. As stated, streaming over PCIe offers the highest transfer speeds of any other streaming option, but maintaining that speed through an entire stream is heavily dependent on the PC and the PC's operating system. Keeping up the transfer is very processor intensive, so any other process that is run during the stream could lower the transfer speed and possibly cause dropped data. To provide best performance, it is recommended to use a PC with at least 16 GB RAM, an Intel i5 processor or better, and a Windows 10 or 11 operating system. Ideally, the IQ Signal Master should also be given the highest priority of any application.

Streaming over Ethernet will also be impacted by possibly variable transfer speeds, but for a different reason. The amount of data that can be transferred over Ethernet will not likely overrun the processor, but will be limited by network bandwidth. If the connection between the PC and the instrument is on an open network, the transfer speeds could fluctuate enough to cause gaps in the data as other traffic is transmitted over the network. Again, the more isolation the system has from outside processes, the better.

To set up a PCIe stream, the first step is to set up the hardware configuration (Figure 5). A tower PC is required because a PCIe card must be installed into the PC motherboard. It has the proper connector and interface to manage the stream. The MA25101A PCIe Streaming Kit (Figure 6) includes the PCIe card, brackets for both slim and wide PCs, and the required PCIe cable to connect the PC to the Field Master Pro. When it is all set up, the configuration will look like the one in Figure 7. Once the hardware is configured and connected correctly, the IQ Signal Master can be used to setup and control the stream. Detailed instructions are given in the MX280005A User Guide.

Ethernet

PCIe

Nanopitch cable supplied with MA25101A
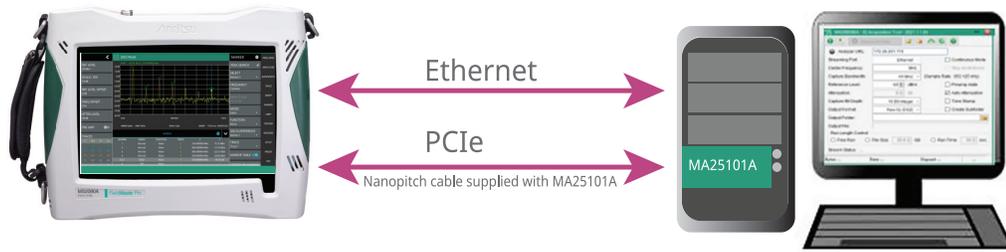
MA25101A

Figure 5. PCIe Streaming Configuration

Figure 6. MA25101A PCIe Streaming Kit

Figure 7. Field Master Pro Connected to PC for IQ Streaming

Setting up an Ethernet stream is similar, but simpler. As long as the Field Master Pro and PC are on the same network (the PC will be able to ping the IP address of the instrument), the IQ Acquisition Tool can manage the rest.

X-COM IQC500B

The final option for output option for IQ streaming is the IQC5000B RF Record and Playback System from X-COM. X-COM tools have been common in the intelligence community for decades, but until now only had streaming capabilities with bulky, expensive benchtop instruments. With the integration of the Field Master Pro for IQ streaming, measurements that were reserved for the lab can now be taken to the field. The IQC5000B supports > 800 MB/s of stable transfer rates, which enables full 110 MHz bandwidth streaming at 16 bit resolution. It also has storage options up to 14 TB of data and integrates data seamlessly with X-COM's powerful Spectro-X software tool for post-processing of the IQ data.

Streaming to the IQC5000B is much like the streaming PC setup. The IQC5000B software controls the stream and manages the data. The hardware setup requires the MA25424A IQ Converter Kit, which includes the converter box, a USB 3.0 cable, and a PCIe cable. The box converts the data into an LVDS format for final receiving by the IQC5000B. See Figure 8 for a diagram of the hardware setup.
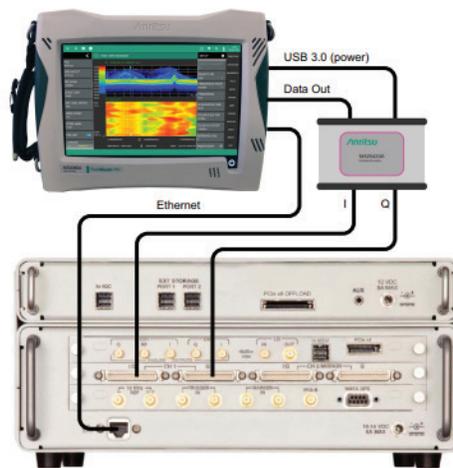
Figure 8. Hardware Setup to Stream IQ Data from Field Master Pro to IQC5000B

To set up a stream to the IQC5000B, select "Data Out" from the OUTPUT PORT selection, then in DATA OUT FORMAT select IQC.
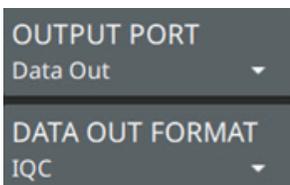
Conclusion

The Field Master Pro MS2090A offers the best combination of frequency coverage, measurement bandwidth and RF performance of any instrument capable of streaming IQ data in the field. This is all delivered in a compact size with a battery operation. With best-in-class specifications and features, the Field Master Pro MS2090A is opening new doors and taking signal intelligence to the field.

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Specifications are subject to change without notice.

• United States
Anritsu Americas Sales Company
450 Century Parkway, Suite 190, Allen, TX 75013 U.S.A.
Phone: +1-800-Anritsu (1-800-267-4878)

• Canada
Anritsu Electronics Ltd.
Americas Sales and Support
450 Century Parkway, Suite 190, Allen, TX 75013 U.S.A.
Phone: +1-800-Anritsu (1-800-267-4878)

• Brazil
Anritsu Eletronica Ltda.
Praça Amadeu Amaral, 27 - 1 Andar
01327-010 - Bela Vista - Sao Paulo - SP, Brazil
Phone: +55-11-3283-2511
Fax: +55-11-3288-6940

• Mexico
Anritsu Company, S.A. de C.V.
Blvd Miguel de Cervantes Saavedra #169 Piso 1, Col. Granada
Mexico, Ciudad de Mexico, 11520, MEXICO
Phone: +52-55-4169-7104

• United Kingdom
Anritsu EMEA Ltd.
200 Capability Green, Luton, Bedfordshire, LU1 3LU, U.K.
Phone: +44-1582-433200
Fax: +44-1582-731303

• France
Anritsu S.A.
12 avenue du Québec, Immeuble Goyave,
91140 VILLEBON SUR YVETTE, France
Phone: +33-1-60-92-15-50

• Germany
Anritsu GmbH
Nemetschek Haus, Konrad-Zuse-Platz 1,
81829 München, Germany
Phone: +49-89-442308-0
Fax: +49-89-442308-55

• Italy
Anritsu S.r.l.
Spaces Eur Arte, Viale dell'Arte 25, 00144 Roma, Italy
Phone: +39-6-509-9711

• Sweden
Anritsu AB
Kistagången 20 B, 2 tr, 164 40 Kista, Sweden
Phone: +46-8-534-707-00

• Finland
Anritsu AB
Technopolis Aviapolis, Teknobulevardi 3-5 (D208.5.),
FI-01530 Vantaa, Finland
Phone: +358-20-741-8100

• Denmark
Anritsu A/S
c/o Regus Winghouse, Ørestads Boulevard 73, 4th floor,
2300 Copenhagen S, Denmark
Phone: +45-7211-2200

• Spain
Anritsu EMEA Ltd.
Representation Office in Spain
Paseo de la Castellana, 141. Planta 5, Edificio Cuzco IV
28046, Madrid, Spain
Phone: +34-91-572-6761

• Austria
Anritsu EMEA GmbH
Am Belvedere 10, A-1100 Vienna, Austria
Phone: +43-(0)1-717-28-710

• United Arab Emirates
Anritsu EMEA Ltd.
Anritsu A/S
Office No. 164, Building 17, Dubai Internet City
P. O. Box – 501901, Dubai, United Arab Emirates
Phone: +971-4-3758479

• India
Anritsu India Private Limited
6th Floor, Indiqube ETA, No.38/4, Adjacent to EMC2,
Doddanekundi, Outer Ring Road, Bengaluru – 560048, India
Phone: +91-80-6728-1300
Fax: +91-80-6728-1301

• Singapore
Anritsu Pte. Ltd.
1 Jalan Kilang Timor, #07-04/06 Pacific Tech Centre
Singapore 159303
Phone: +65-6282-2400
Fax: +65-6282-2533

• Vietnam
Anritsu Company Limited
16th Floor, Peakview Tower, 36 Hoang Cau Street, O Cho Dua Ward,
Dong Da District, Hanoi, Vietnam
Phone: +84-24-3201-2730

• P.R. China (Shanghai)
Anritsu (China) Co., Ltd.
Room 2701-2705, Tower A, New Caohejing International
Business Center No. 391 Gui Ping Road Shanghai, 200233, P.R. China
Phone: +86-21-6237-0898
Fax: +86-21-6237-0899

• P.R. China (Hong Kong)
Anritsu Company Ltd.
Unit 1006-7, 10/F., Greenfield Tower, Concordia Plaza,
No. 1 Science Museum Road, Tsim Sha Tsui East,
Kowloon, Hong Kong, P.R. China
Phone: +852-2301-4980
Fax: +852-2301-3545

• Japan
Anritsu Corporation
8-5, Tamura-cho, Atsugi-shi, Kanagawa, 243-0016 Japan
Phone: +81-46-296-6509
Fax: +81-46-225-8352

• Korea
Anritsu Corporation, Ltd.
8F, A TOWER, 20, Gwacheondaero 7-gil, Gwacheon-si,
Gyeonggi-do, 13840, Republic of Korea
Phone: +82-2-6259-7300
Fax: +82-2-6259-7301

• Australia
Anritsu Pty. Ltd.
Unit 20, 21-35 Ricketts Road, Mount Waverley, Victoria 3149, Australia
Phone: +61-3-9558-8177
Fax: +61-3-9558-8255

• Taiwan
Anritsu Company Inc.
7F, No. 316, Sec. 1, NeiHu Rd., Taipei 114, Taiwan
Phone: +886-2-8751-1816
Fax: +886-2-8751-1817

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