Anritsu envision : ensure

Accessing 43.5 GHz Measurements with Traceability

As more people become accustomed to technology, the demand for data throughput has increased exponentially both in telecommunication and defense applications. Emerging telecommunication technologies, such as 5G and high throughput satellite (HTS) systems, are being proposed to operate at 20 GHz to 43.5 GHz millimeter-wave (mmWave) frequency bands in order to satisfy the demand.

Migration of communication systems to higher frequencies requires test equipment and systems that are able to make measurements in new mmWave frequency bands that extend up to 43.5 GHz. Test and measurement (T&M) equipment manufacturers have responded to the need by introducing upgraded products that extend the upper frequency limit from 40 GHz to 43.5 GHz.

Along with the frequency extension, T&M equipment vendors also have to find a replacement for the K (2.92 mm) input/output connectors and components needed while using their products as K only operates up to 40 GHz. Replacing a K connector/component with any higher frequency connector (such as 2.4 mm) carries a higher cost burden on users of the test equipment.

This gives rise to the need for precision components and connectors that continue to leverage the K connector and extends its operating, mode-free performance from 40 to 43.5 GHz. Furthermore, a measurement is only as good as the components that carry and receive a signal from the test equipment. In turn, these components are only as good as connectors at their input and output. Hence in addition to frequency extension, establishing a clear path of traceability is critical.

This application note will explore: application drivers for 43.5 GHz development; connector fundamentals; what traceability is and why it is important; connectors for 43.5 GHz applications; and finally, current solutions on the market that can address 43.5 GHz operation with traceability.

What is Driving the 43.5 GHz Frequency Requirement?

There are several emerging verticals in the frequency bands between 20 to 43.5 GHz, especially in the 37 to 43.5 GHz bands, such as: microwave backhaul radio links for 5G mobile and enterprise networks, HTS Satellite Systems, Advanced Extremely High Frequency (AEHF) satellite systems and mmWave body scanners. These new systems will require connectors, components, and test equipment that can access the 43.5 GHz frequency bandwidth while also providing traceability.

Travel is an important part of business and economic sector. With increased growth of airport traffic, throughput is an important factor but it must be weighed against risks for unapproved or dangerous cargo. Not too long ago, a simple pat down or metal detector was enough, but times have changed, and now new methods are in place to reduce risk to people and aircraft. Millimeter body scanners are now deployed across many countries. A mmWave body scanner uses low frequency components at the source then up-convert the signal to 42 GHz at the transmission stage of the machine. On the receive end, 42 GHz signals are acquired and translated down to low frequency to be processed. This creates an environment where all receive and transmit components like mixers, amplifiers, and antennas in the 42 GHz frequency range must be tested (Figure 1). This is also a sensitive area where uncertainty budget is critical as precision measurements are needed to guarantee the accuracy of the body scanners.

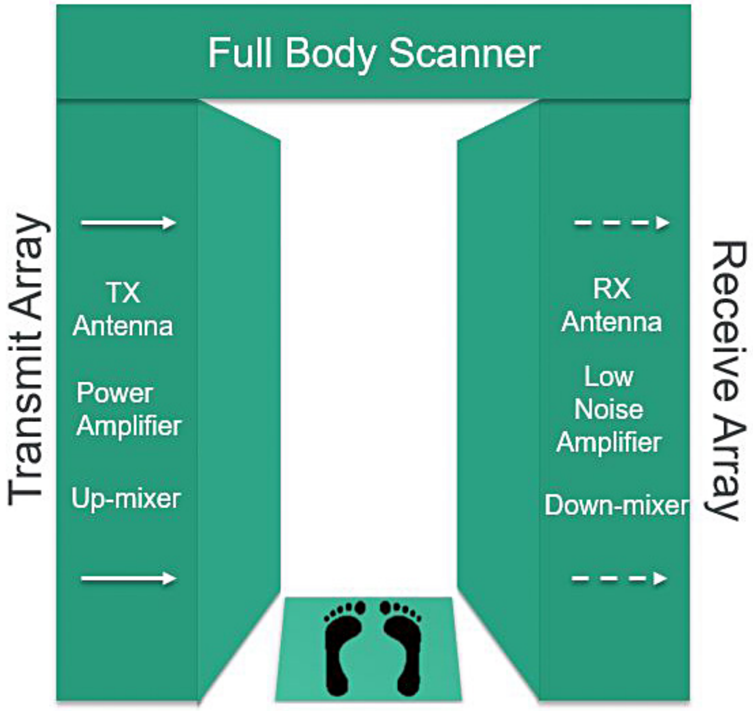

Figure 1. Block Diagram of a mmWave Body Scanner

Another smaller application where frequency coverage extends into the 43 GHz range is advanced extremely high frequency (AEHF). Government and defense applications with satellite technology require uplink rates over 40 GHz. These communication systems are strategically important, and like body scanners, require and a stringent uncertainty budget.

The largest market with new mmWave requirements is telecommunications. 5G is currently the biggest buzzword around telecommunications and rightfully so as deployments are beginning to happen. While the picture was not as clear during the transition away from 4G protocols, one very big change is the use of microwave and mmWave frequency bands that accommodate different purposes in the communication chain. While most of the legacy frequency bands already in use fall into standard frequency bands of test equipment like: 10, 20, and 40 GHz, the 5G spectrum of 37 to 43.5 GHz has created an environment all on its own.

While initial 5G New Radio (NR) deployments are targeting the sub-6 GHz spectrum, those in the mmWave range (above 24 GHz) will be the ones that provide immense amounts of bandwidth. The United States FCC proposed, in June 2018, using 42 to 42.5 GHz for commercial broadband or fixed services, while Brazil and Mexico have similar proposals for mobile broadband within the 37 to 43.5 GHz frequency range. Japan and the EU also have proposals in the 40.5 to 43.5 GHz range for similar mobile broadband functionality (Figure 2).

While a lot of countries are in the proposal state of millimeter frequency 5G development, China's Ministry of Industry and Information Technology (MIIT) has been at the forefront of 5G development for research and development testing. [2] China has not only proposed frequencies for their 5G development, they have had 5G Technology R&D trials as well as Product R&D trials. South Korea is also an upcoming leader in millimeter 5G deployment up to 43.5 GHz.

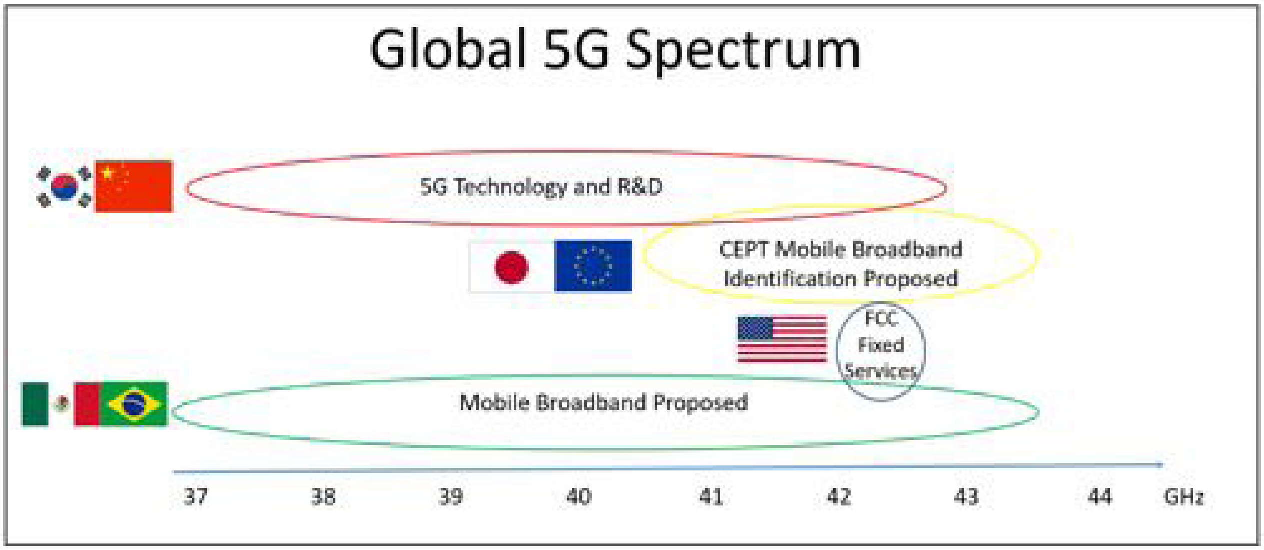

Figure 2. Global 5G Spectrum Frequency Allocations by Countries and Application [2]

Clearly, markets such as 5G, mmWave body scanners, and AEHF are driving semiconductor, module, and equipment suppliers to those markets and instrumentation suppliers to extend their frequencies to 43.5 GHz.

Reaction from the Test and Measurement Market

The change in frequency coverage over the last few years has been quietly incorporated by many T&M companies, adding this frequency option to their existing and new products. One of the many aspects of providing 43.5 GHz frequency coverage is how T&M companies propose to transition the user to the extended frequency coverage of 43.5 GHz while making measurements.

There are two approaches to getting a user to 43.5 GHz that are in practice currently. The first is to have the test equipment fitted with 2.4 mm connectors. This option has a dual purpose. First and foremost, it can easily accomplish performance to 50 GHz on the connector as well as establish traceability. However, one issue with this approach is that a user will have to replace all cabling, calibration kits (if necessary), adapters, and all other components to those with a 2.4 mm connector. This now becomes a costly endeavor, as 2.4 mm components are traditionally more expensive than 2.92 mm solutions. Another issue that arises are the many devices under test (DUTs) that have K connectors (2.92 mm). Users will need to incorporate an adapter in to their test solution. While most manufacturers that have a 2.4 mm connector type will offer an adapter to 2.92 mm, unless that solution is rated/specified to 43.5 GHz on the 2.92 mm side, performance will not be achieved to 43.5 GHz. This is due in part to the issue of over-moding (the creation of modes on the connector). We will visit this concept in much greater detail later.

The second approach is to fit the instruments with 2.92 mm connectors and state the instrument can make measurements to 43.5 GHz with the caveat that the 40 to 43.5 GHz specifications are “measured”. This approach has some drawbacks in that without specifications, the connectors are most likely not tested individually and are part of a catch all approach with instrument specifications. Of course, traceability cannot be stated using the “measured” approach.

Connector Design: THE Single-Most Important Part of the Equation

Two of the most important aspects of a connector’s electrical performance is its frequency scalability and whether it can address performance requirements to the target frequency of 43.5 GHz. To achieve optimal electrical performance, one major consideration has to do with mode propagation in the connector. The upper frequency of a connector can be determined using the general equation provided below and for the K connector it is approximately 46 GHz assuming a perfect air dielectric.

$$f_c = \frac{c}{\lambda_c\sqrt{\mu_r\epsilon_r}} \qquad [3]$$

For the equation: fc is the air cutoff frequency; c is the speed of light at 3.0 E8 m/s; ϵr is the relative permittivity; μr is the relative permeability; and, λc is the line length.

Practically speaking, the cut-off frequency is actually lower due to the dielectric support beads required to make the connector useful. Because the wavelength shrinks for a given frequency in that dielectric, additional modes can propagate at lower frequencies and this is why most K connectors are specified to 40 GHz.

To truly understand the complexity of bringing a 40 GHz connector up to 94% of its theoretical limit, common issues should be noted. As just mentioned, dielectric support beads are necessary for the center conductor of a connector. Figure 3 is an illustration of a connector’s anatomy.

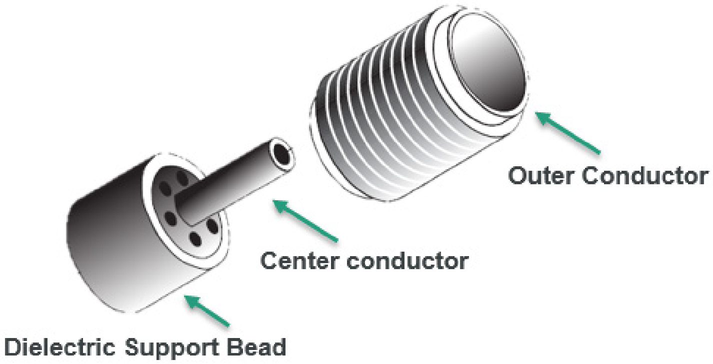

Figure 3. Connector Components

Above the K connector cutoff frequency, an additional mode (labeled TE11 in Figure 4, which is not transverse) can propagate [4] and other modes can propagate at even higher frequencies. This can present a problem in that energy from the input signal can exchange back and forth between the modes depending on small imperfections in the bead surface. Since the modes have different impedances and phase velocities, this can lead to a resonant response in transmission or reflection. The energy interchange is illustrated in Figure 4.

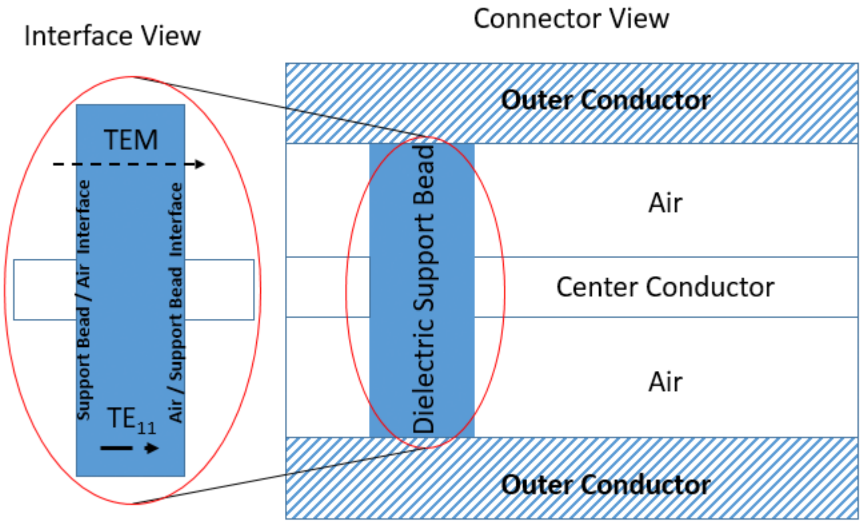

Figure 4: Over-moding condition at the air-dielectric support bead-air interface

The effect of over-moding within the connectors will reveal itself during measurements. This is clearly visible in a transmission measurement of the connector and will result in a large attenuation spike within a small frequency bandwidth. Once the mode resonance has passed (the coupling of energy between modes is not as efficient), the trace will return back to the original transmission path. Over-moding response on a K connector is shown in Figure 5.

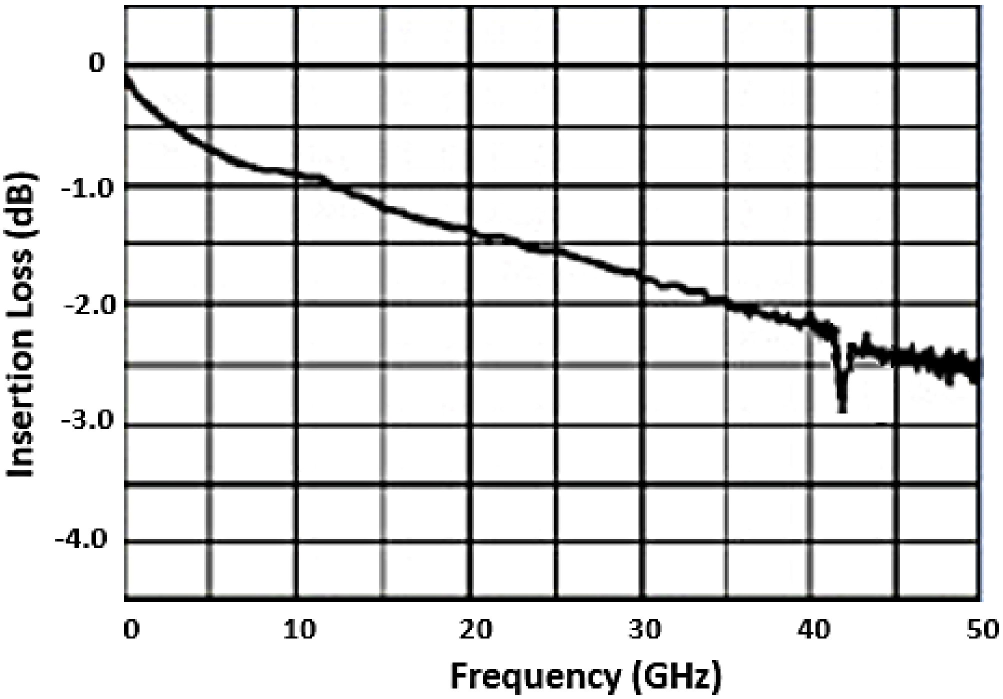

Figure 5. Generic over-moded transmission response at 42 GHz [5]

There are ways to avoid over-moding (e.g., reducing the dielectric bead circumference, optimizing the bead impedance, etc.) and steps can be taken to reduce the chance of energy coupling into the mode (e.g., by tightening other tolerances, etc.).

Assuming that a manufacturer overcomes all the obstacles of over-moding their connector past 40 GHz, is there enough confidence in their measurements? The answer to that varies from application to application based on how stringent the test specifications need to be. For the most part, this information can be shown in datasheets where the performance is qualified as a hard specification or a measured specification.

Measured vs. Specified Performance

A term for establishing electrical specifications that is becoming more prevalent for the >40 to 43.5 GHz region of test instruments is “measured”. A “measured” or characteristic specification refers to measurements that have provided a reasonable set of data that can be quantified, with some level of confidence, and determined to be representative of all units. This is not an uncommon approach to setting electrical specifications. However, the difference between the “measured” data provided and specifications below 40 GHz is that the uncertainty budget is clearly defined through an unbroken chain of traceability, whereas the measurements between 40 to 43.5 GHz generally are not. For manufacturers, uncertainty budget may be important as a measurement on their product will either establish conformance or non-conformance to a particular required specification.

What is Traceability and Why is it Important?

As mentioned earlier, traceability is the path to establishing a solid uncertainty budget. Traceability is much more than an uncertainty budget though, it is also a quality assurance system whose results can be tied to a recognized national metrology institute like NIST or METAS.

Not all connectors can be traceable. One example is the SubMiniature version A (SMA) connector. While used extensively, it is not usually considered traceable due to its dielectric interface, lack of standardization, and low levels of repeatability. This is why SMA connectors do not support precision measurements.

Fortunately, the K connector's basic characteristics can support traceability and, with careful design, can achieve reasonable and documentable uncertainties to 43.5 GHz. The most fundamental aspect of traceability for the connector is impedance, which depends on dimensional assessment and control in airlines used to measure the connectors. Dimensional measurements are performed with traceable tools such as laser micrometers, coordinate measuring devices, and air gages. Once these measurements have been made, the next step in determining traceability is to link airline performance through calibration kits and other components to the individual connector. Some of the measurement quantities used to assess the connectors are outlined in IEEE P287 Standard for Coaxial Connectors. [6] A general path of traceability can be seen in Figure 6.

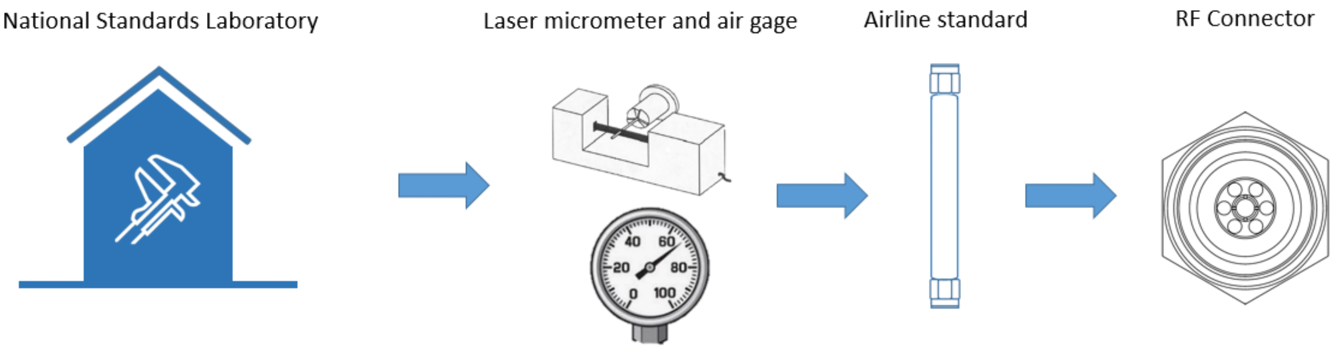

Figure 6. Traceability Path for RF Connectors

Current Solutions

Users that need to meet the 43.5 GHz demand have used 2.4 mm connectors in the past and while it is a traceable and dependable solution, it may not be the most economical. Cost of change for users with already established 2.92 mm R&D, production, or test environments can be quite high since most test systems will have auxiliary equipment like adapters, cables, and calibration kits. Migration to a more expensive 50 GHz platform in the form of 2.4 mm support can be especially difficult for price sensitive customers that are budget constrained.

Anritsu has introduced a new line of 2.92 mm connectors, Extended-K™, that can extend frequency to 43.5 GHz. These new connectors feature the robust design of current Anritsu K connectors but with guaranteed specifications to 43.5 GHz, traceability and mode-free performance. Anritsu features connectors for cables, sparkplug connectors, as well as 2- and 4-screw flange connectors for maximum flexibility of interface requirements.

Anritsu also features Extended-K technology in a limited set of components. Extended-K components utilize Extended-K connectors, provide traceable specifications to 43.5 GHz without over-moding, and do not require the costly investment of moving to 2.4 mm connectors.

The new 33K series adapters that are phase-insertable allowing users flexibility in calibration and measurements up to 43.5 GHz. The new 3670AK semi-rigid test port cables have Extended-K functionality and offer great specifications and mode-free performance to 43.5 GHz.

For users that have 2.4 mm test port connectors and need to reach 43.5 GHz as well as offer compatibility for existing components, the 34KV adapters can accomplish this. The 34K adapters also traceable and allow the user to accurately quantify their uncertainty budget.

Users that require not only the test components but the test systems for measurements in the 43.5 GHz range can now get this functionality with Anritsu ShockLine™ vector network analyzers (VNAs). The Anritsu ShockLine VNAs also feature Extended-K functionality up to 43.5 GHz. ShockLine VNAs are the workhorse of manufacturing instruments for S-parameter testing. Any ShockLine VNA combined with a portable Thru-Open-Short-Load calibration kit in both male and female gender (TOSLK50A-43.5 and TOSLKF50A-43.5) offer a complete system of mode-free performance and an unbroken chain of traceability back to a national metrology institute.

References:

1. Analog Devices. (2020, January 5). Millimeter Wave Body Scanners Market: Past, Present, and Future. Retrieved from https://www.analog.com/en/technical-articles/millimeter-wave-body-scanners-market-past-present-and-future.html

2. 5G Americas. 5G Spectrum Vision. Feb. 2019. http://www.5gamericas.org/files/4015/4958/3330/5G_Americas_5G_Spectrum_Vision_Whitepaper.pdf

3. Oldfield, B (2007). The Importance of Coax Connector Design Above 110 GHz. Anritsu Co. Retrieved from https://dl.cdn-anritsu.com/ja-jp/test-measurement/reffiles/About-Anritsu/R_D/Technical/E-22/22_07.pdf

4. Williams, B. (May 2004) ANAMET Report 044. “Overmoding transmission characteristics of Type-N connector 7 mm line between 18 and 26.5 GHz”. Middlesex, UK. National Physics Laboratory. http://resource.npl.co.uk/docs/networks/anamet/members_only/publications/report_044.pdf

5. Fuks, R. (2001). New Dielectric Bead for Millimeter-wave Coaxial Components. Microwave Journal, 13. https://www.microwavejournal.com/articles/3205-new-dielectric-bead-for-millimeter-wave-coaxial-components

6. IEEE Instrumentation and Measurement Society. IEEE Standard for Precision Coaxial Connectors (DC to 110 GHz). New York, NY: Office Headquarters. 2007.

envision : ensure

Specifications are subject to change without notice.

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

• Canada
Anritsu Electronics Ltd.
700 Silver Seven Road, Suite 120,
Kanata, Ontario K2V 1C3, Canada
Phone: +1-613-591-2003
Fax: +1-613-591-1006

• Brazil
Anritsu Electrônica 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, Batiment Iris 1-Silic 612,
91140 VILLEBON-SUR-YETTE, France
Phone: +33-1-60-92-15-50
Fax: +33-1-64-46-10-65

• 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.
Via Elio Vittorini 129, 00144 Roma Italy
Phone: +39-06-509-9711
Fax: +39-6-502-2425

• Sweden
Anritsu AB
Isafjordsgatan 32C, 164 40 KISTA, Sweden
Phone: +46-8-534-707-00

• Finland
Anritsu AB
Teknobulevardi 3-5, FI-01530 VANTAA, Finland
Phone: +358-20-741-8100
Fax: +358-20-741-8111

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

• Russia
Anritsu EMEA Ltd.
Representation Office in Russia
Tverskaya str. 16/2, bld. 1, 7th floor.
Moscow, 125009, Russia
Phone: +7-495-363-1694
Fax: +7-495-935-8962

• Spain
Anritsu EMEA Ltd.
Representation Office in Spain
Edificio Cuzco IV, Po. de la Castellana, 141, Pta. 5
28046, Madrid, Spain
Phone: +34-915-726-761
Fax: +34-915-726-621

• United Arab Emirates
Anritsu EMEA Ltd.
Dubai Liaison Office
902, Aurora Tower,
P O Box: 500311- Dubai Internet City
Dubai, United Arab Emirates
Phone: +971-4-3758479
Fax: +971-4-4249036

• India
Anritsu India Pvt Ltd.
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.
11 Chang Charn Road, #04-01, Shriro House
Singapore 159640
Phone: +65-6282-2400
Fax: +65-6282-2533

• Vietnam
Anritsu Company Limited
Room No. 1635, 16th Floor, ICON 4 Tower, 243A De La
Thanh Street,
Lang Thuong Ward, Dong Da District, Hanoi, Vietnam
Phone: +84-24-3760-6216
Fax: +84-24-6266-2608

• 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.
5FL, 235 Pangyoyeok-ro, Bundang-gu, Seongnam-si,
Gyeonggi-do, 13494 Korea
Phone: +82-31-696-7750
Fax: +82-31-696-7751

• 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

nqa. ISO 9001 Registered

11410-01165, Rev. B Printed in United States 2020-06