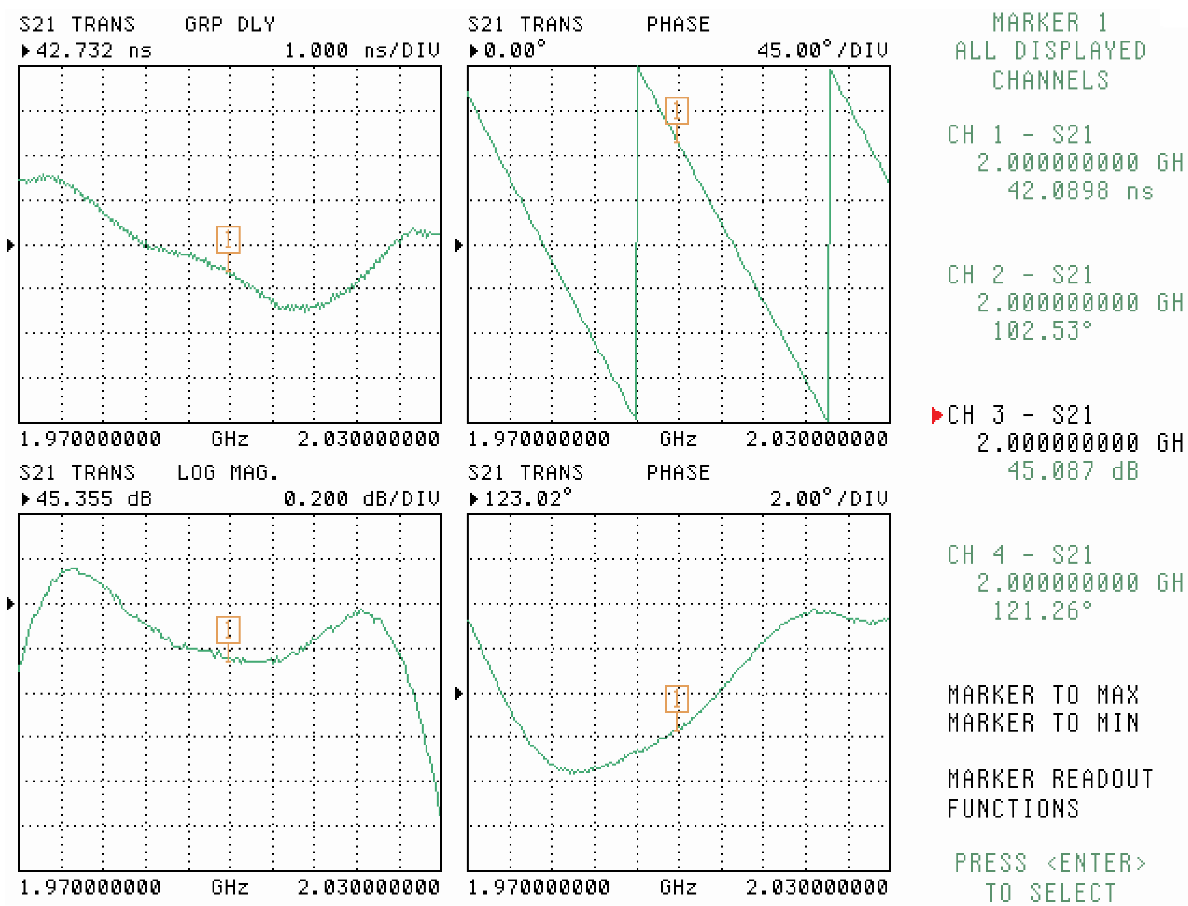
Anritsu

Scorpion®

TECHNICAL NOTE

Procedure to Measure Dual Converters with LO Access

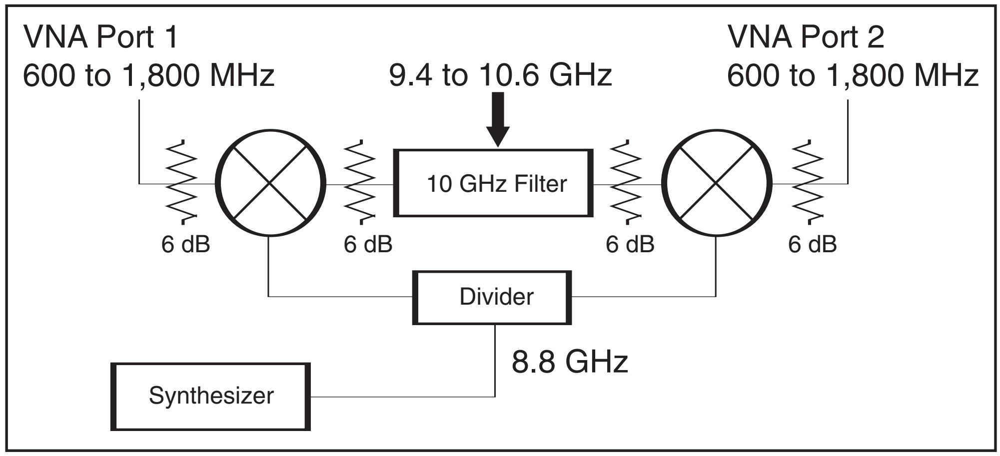
Following this procedure will provide measurements of converter group delay, gain, phase and deviation from linear phase (typical data shown below). The DUT is a dual down-converter. Fast sweep speed permits tuning.



General Information

The approach which this paper describes is the most accurate, repeatable and flexible method to measure single and dual converters available today. However, it does require samples of the converter under test LO's, which are then amplified and used to drive the LO inputs of two external mixers. These mixers are characterized individually in S2P format by the user, using Anritsu Mixer Assistant Software Ver 3.13 P/N 2300-232, also known as N X N software which refers to the three equations in three unknown solution it incorporates. Due to the high SWR of mixers, attenuators must be appropriately placed around them. These must be accounted for so conversion gain and propagation time will be accurate. Since converters can have appreciable gain and VNA's have high dynamic range, the addition of lossy devices such as mixers and attenuators does not present a problem.

Mixer characterization must be accomplished over the same LO frequency, RF Frequency and LO Power levels which will be present during converter testing. Therefore, some knowledge of the converter under test is required. Communications receivers are generally tested with their LOs fixed and with a swept RF input. This is also known as swept IF, allowing Group Delay (GD), Deviation from Linear Phase, as well as Absolute Gain and Gain Flatness across the IF bandwidth to be measured. Sweeping slightly wider than the BW of the IF is suggested to see responses which are past the band edges.

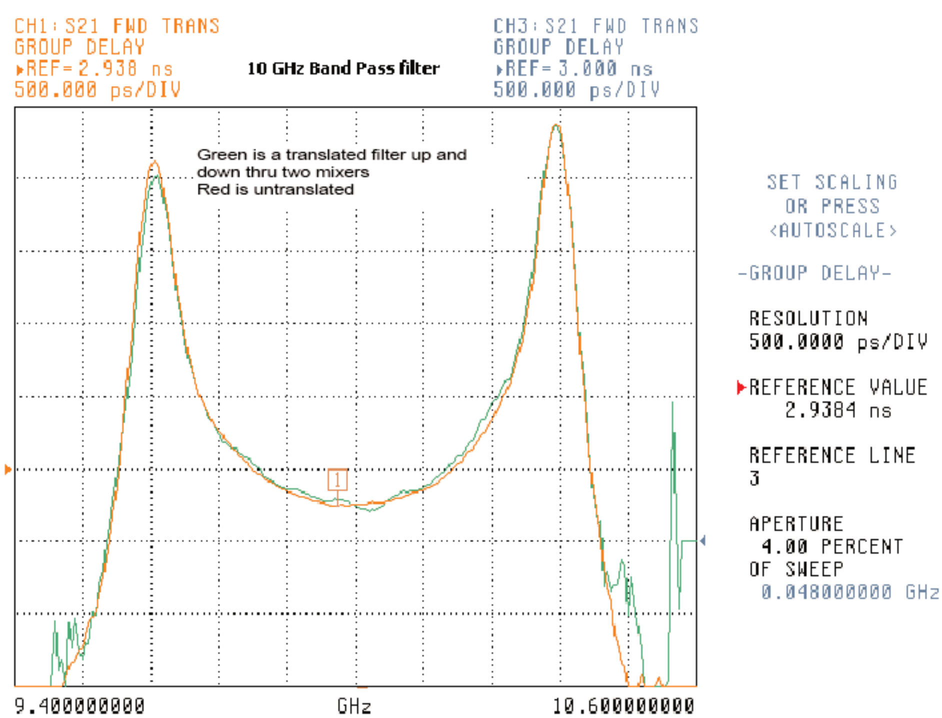


Setup to Verify the Converted Filter Measurement

Where only GD measurements are required, mixers can be added which have not been characterized, provided the frequencies of operation are not near the upper or lower limits of the mixers and the IF BW's are typical for those used in communications. The concept can be proven by simply measuring the GD of a filter (NIST traceable measurement) and then comparing the data taken when mixers are added before and after the filter. The net result of the two mixers is up and down conversion using a common LO, thereby forcing the same frequency to be present at both the measurement and reference channels of the Vector Network Analyzer. In essence this is a conventional S21 measurement the VNA does not "feel" the translation. This entire paper is based on this up convert/down conversion premise.

Below is a plot of data taken with the this set- up with a full two port calibration applied.

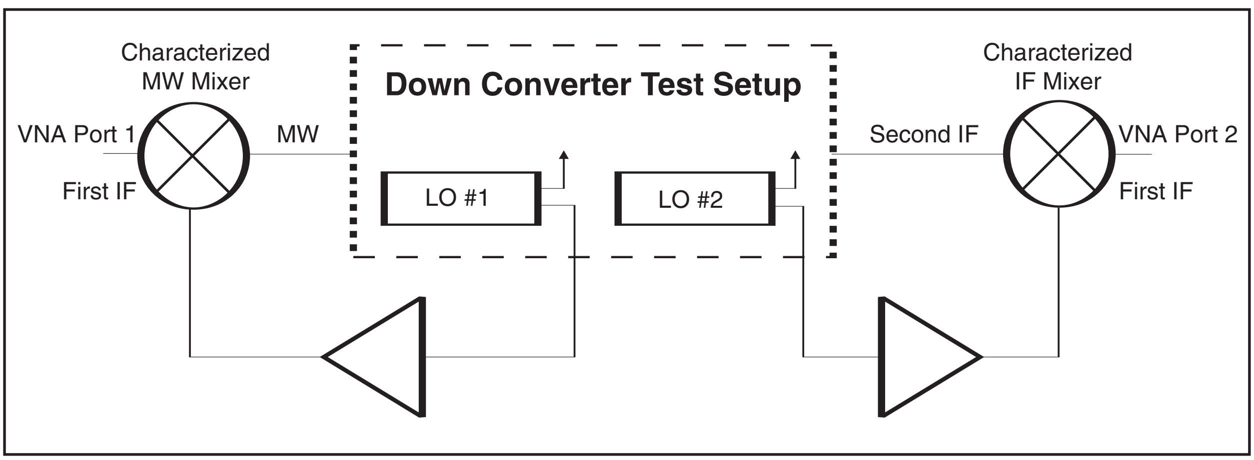
Please note the scale (500 psec/div).



Full Two Port Calibration Applied

Note that there is no significant difference between the non-translated measurement which is NIST traceable (red trace) and the green trace which has two stages of frequency translation. Only absolute delay or propagation time thru the network is affected by the mixers (as indicated by the differences in the reference level). A dual converter is essentially composed of two stages of mixing, filtering and amplification. One should not lose sight of the fact that microwave instruments in general utilize translated data, as do receivers. The Anritsu series of Lightning VNA's is triple converted and the Scorpion series is single converted, so the addition of external conversion is valid, provided the mixers are properly characterized and de-embedded. Both series of analyzers have S2P de-embed capability. With this approach, data is taken at the first IF, so either series can be used; however, only the Lightning series can be used where return loss or mixer characterization is required above 9 GHz. Mixer characterization is required for gain and absolute phase (propagation time through the converter). GD and deviation from linear phase can be measured without the use of characterized mixers. Group delay is the "shape" of the delay versus frequency as the signal is swept across the IF BW of the converter under test (mathematically it is the negative of the first derivative of phase versus frequency). Some band–pass filter group delays are parabolic in nature as can be seen from region between the peaks of the filter shown above. Receiver GD is ideally parabolic also. Receiver designers usually design their converters so the anticipated occupied BW covers the center third of the IF band-pass (the region where the GD and amplitude are essentially flat). By doing so, phase and amplitude of translated signals can be faithfully reproduced. Up-converters and Down-converters today can have parabolic GD as small a 1 nanosec over an IF range of 50 to 90 MHz. GD can also be specified over narrower slices of frequency within the IF range. The setup for measuring a dual converter is shown below.

Note - for a dual converted up converter the external mixers function as two stages of down conversion. For down converters the external mixers both function as up converters.



Down Converter Test Setup

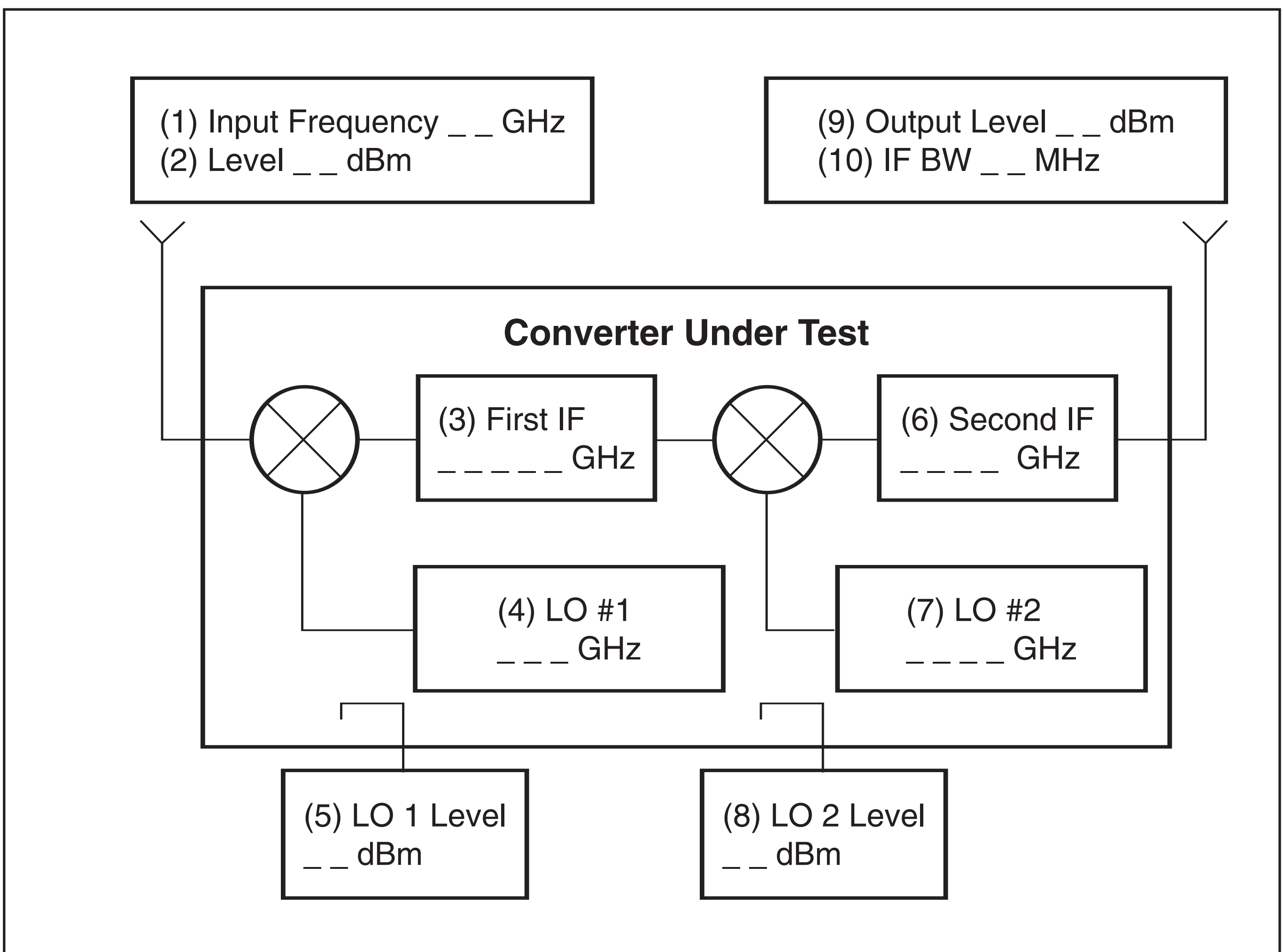
Up converters can be tested with a similar set-up, by reversing the positions of the external mixers. There are two benefits of this approach which are not immediately obvious:

(1) Mixers generate many mixing products (predominantly the upper and lower sidebands), placement of the MW mixer as shown uses the converter under test itself to filter out the undesired products and pass only the desired signal.

(2) This technique also results in lower measurement uncertainty due to the reduction of LO phase noise. Phase noise on the DUT LO's is a prime contributor to GD measurement uncertainty for VNA based GD measurements; however, taking a sample of the LO from the converter under test and amplifying it to a sufficient level to drive an external mixer, as shown above, will cause the phase noise of each LO to be subtracted from itself ! This yields lower noise GD measurements than can be achieved with external synthesizers even if their clocks are locked together. It also eliminates the need for external LO synthesizers during testing (One synthesizer is required, but only during mixer characterization). A common question is "Why not use a single mixer either before or after the converter under test to bring the frequency back to the original frequency? Answer – if a single mixer is used to re-convert the VNA input back to the original frequency, you now have three sources of phase noise with none of them being subtracted out. While there is a technique to reconstitute the LO's from the input and output frequencies of the converter under test, results do not indicate the level of GD noise shown with the procedures describes here.

Before mixer characterization can be accomplished, some knowledge of the converter under test must be obtained. Record this information on the dotted lines below, referring to the drawing below it for clarification of terms.

1. Input Frequency	____________	GHz
2. Input Level	____________	dBm
3. First IF Frequency	____________	GHz
4. First LO Frequency	____________	GHz
5. First LO Sample Power	____________	dBm
6. Second IF Frequency	____________	GHz
7. Second LO Frequency	____________	GHz
8. Second LO Sample Power	____________	dBm
9. Second IF Output Level	____________	dBm
10. IF BW	____________	MHz
11. Conversion Gain (9) minus (2)	____________	dB

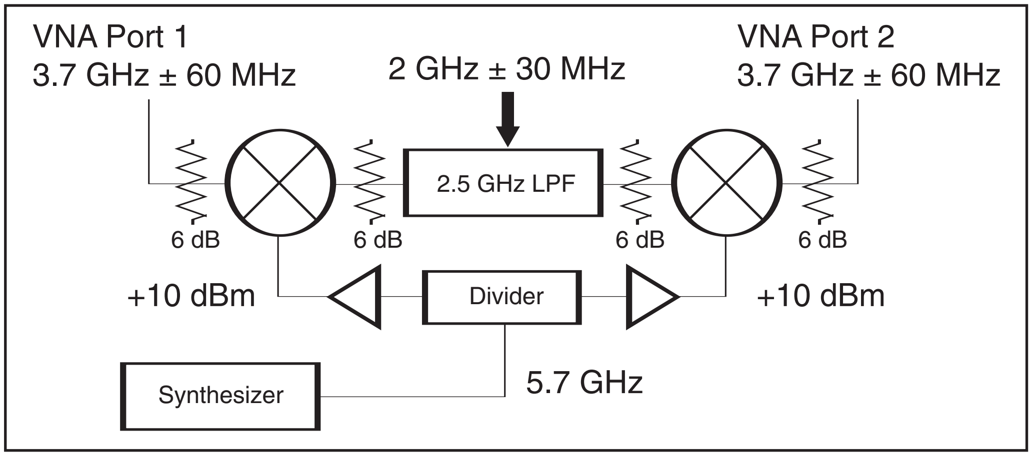


Converter Under Test Block Diagram

Detailed Procedure

Mixer Assistant Software Requirements

To use the mixer assistant software a PC with GPIB, a synthesizer, three mixers, a power divider, a filter and two amplifiers with equal gain are required (see below).



Setup for MW Mixer Characterization

Adjust the synthesizer output level so as to obtain the desired LO drive (+7 dBm is usually sufficient, however +10 will assure saturation) at both mixer LO inputs. Balance the levels with attenuators if necessary. The filter must have at least 30 dB of rejection for undesired mixing products. This filter must be able to pass the first IF center frequency and be at least as wide as the converter under test IF BW. A low pass or high pass filter can be used depending on the frequency plan where a band pass filter is not available, provided unwanted products are rejected. In order to characterize a single mixer using the Anritsu Mixer Assistant S/W, three MW mixers and three IF mixers (taken two at a time) are required to measure a dual converter. These mixers need not be matched in any way. The only stipulations being that their insertion loss be <15 dB and one of the three must be a reciprocal device (capable of up and down converting). Once all of the components have been assembled, follow the prompts in the Mixer Assistant Software. During N x N testing it is good practice to compare S21 and S12 of the network. They should be essentially the same if all three mixers have reciprocal characteristics. The software will de-embed all of the components except for one mixer. Save the S2P file* for one MW mixer in the set of three and one IF mixer from the IF mixer set. Be certain to mark these mixers appropriately so their S2P files can be de-embedded correctly during the final phase of converter testing. Refer to Anritsu Application Note "Measuring Frequency Conversion Devices" pn: 11410-00197 for additional information on mixer testing.

Note – The S2P de-embed referred to here is not a traditional S2P de-embed, in that only the transmission terms (S21 and S12) are used. The frequencies used in the de-embedding process are the frequencies seen by the VNA so the frequency column of the s2p file may need to be reconstructed or re-indexed.

Example

Converter Under Test Specifications (required to characterize the mixers)

1. Input Frequency	3.7 GHz
2. Input Level	–45 dBm
3. First IF Frequency	2.0 GHz
4. First LO Frequency	5.7 GHz
5. First LO Sample Power	–2.76dBm
6. Second IF Frequency	.070 GHz
7. Second LO Frequency	2.07 GHz
8. Second LO Sample Power	–9.9 dBm
9. Second IF Output Level	0 dBm
10. IF BW	040 GHz*
11. Conversion Gain (9) minus (2)	45 dB

Test range .060 GHz (1.97 to 2.03 GHz)

1. In this example the first IF frequency is 2 GHz; therefore a 2.5 GHz low pass filter was selected.
2. The first LO sample level is –10 dBm (@ 5.7 GHz) so an amplifier with 20 dB of gain was selected with a +20 dBm 1 dB compression point.
3. Three 20 GHz MW mixers were selected at random for use with the mixer assistant S/W along with three IF mixers.
4. An attenuation value of 6 dB was selected to install on both sides of the filter to improve the match to the mixers.
5. Adapters were installed as required to facilitate installation of the filter between the mixers with no change of electrical length.
6. An attenuation value of 6 dB was selected to place on the test ports of the VNA to improve the interaction between the mixers and the test ports.
7. Each VNA calibration should be accomplished with 10 sweep averages and 100 Hz IF BW. This will reduce the noise in the mixer S2P files. Noise on these files cannot be averaged out during the measurement.
8. When the N x N process is completed save the data for one mixer and Assign the file name "**MWMIXS2P**" for use in the converter measurement.
9. For the IF Mixer Characterization the basic setup was the same, except the input frequency was swept from 70 ±30 MHz with an LO of 2.07 GHz and the filter was a 2 GHz Low Pass.
10. When the Mixer Assistant process is completed, assign the file name "**IFMIXS2P**" to the mixer selected as the IF mixer.
11. Connect the mixers and LO amplifiers. Adjust the LO levels with attenuators to match the levels which were used for mixer characterization.
12. Calibrate the VNA at the first IF frequency (2 GHz ±30 MHz), using 100 Hz IF BW and 10 sweep averages. Use the same number of data points as was used in the previous steps and 20 dB of step attenuation (–27 dBm port 1 power). This must be reduced to –45 dBm with the power adjust before connecting the VNA to the converter input.
13. De-Embed the S2P files for the mixers which are on ports one and two. Follow prompts under the utility menu.
14. Power-up the converter and LO amps
15. Set-up the analyzer data points, averaging, and IF BW for speed or lowest noise, (speed for tuning and low noise for data acquisition).
16. Read and record the data (note the set-up can be saved on the hard drive or FD for future re-call as can the S2P files).

Notes

ANRITSU CORPORATION
5-1-1 Onna, Atsugi-shi, Kanagawa, 243-8555 Japan
Phone: +81-46-223-1111
Fax: +81-46-296-1264

- Australia
ANRITSU PTY LTD.
Unit 3/170 Forster Road Mt. Waverley,
Victoria, 3149, Australia
Phone: +61-3-9558-8177
Fax: +61-3-9558-8255

- Brazil
ANRITSU ELETRÔNICA LTDA
Praca Amadeu Amaral, 27-1 andar
01327-010 - Paraiso, Sao Paulo, Brazil
Phone: +55-11-3283-2511
Fax: +55-11-3886940

- Canada
ANRITSU ELECTRONICS LTD.
700 Silver Seven Road, Suite 120, Kanata,
ON K2V 1C3, Canada
Phone: +1-613-591-2003
Fax: +1-613-591-1006

- Denmark
ANRITSU A/S
Kirkebjerg All 90 DK-2605 Brondby, Denmark
Phone: +45-72112200
Fax: +45-72112210

- Finland
ANRITSU AB
Teknobulevardi 3-5, FI-01530 Vantaa, Finland
Phone: +358-9-4355-220
Fax: +358-9-4355-2250

- France
ANRITSU S.A.
9, Avenue du Québec Z.A. de Courtaboeuf 91951 Les
Ulis Cedex, 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 (0) 89 442308-0
Fax: +49 (0) 89 442308-55

- Hong Kong
ANRITSU COMPANY LTD.
Suite 923, 9/F., Chinachem Golden Plaza, 77 Mody
Road, Tsimshatsui East, Kowloon, Hong Kong, China
Phone: +852-2301-4980
Fax: +852-2301-3545

- India
ANRITSU CORPORATION India Liaison Office
Unit No.S-3, Second Floor, Esteem Red Cross Bhavan,
No.26, Race Course Road, Bangalore 560 001 India
Phone: +91-80-30944707

- Italy
ANRITSU S.p.A.
Via Elio Vittorini, 129, 00144 Roma EUR, Italy
Phone: +39-06-509-9711
Fax: +39-06-502-2425

- Korea
ANRITSU CORPORATION
8F Hyun Juk Bldg. 832-41, Yeoksam-dong,
Kangnam-ku, Seoul, 135-080, Korea
Phone: +82-2-553-6603
Fax: +82-2-553-6604

- P. R. China
ANRITSU COMPANY LTD.
Beijing Representative Office
Room 1515, Beijing Fortune Building, No. 5 North Road,
the East 3rd Ring Road, Chao-Yang District
Beijing 100004, P.R. China
Phone: +86-10-6590-9230

- Singapore
ANRITSU PTE LTD.
10, Hoe Chiang Road #07-01/02, Keppel Towers,
Singapore 089315
Phone: +65-6282-2400
Fax: +65-6282-2533

- Sweden
ANRITSU AB
Borgafjordsgatan 13 164 40 Kista, Sweden
Phone: +46-853470700
Fax: +46-853470730

- Taiwan
ANRITSU COMPANY INC.
7F, No. 316, Sec. 1, NeiHu Rd., Taipei, Taiwan
Phone: +886-2-8751-1816
Fax: +886-2-8751-1817

- U.K.
ANRITSU LTD.
200 Capability Green, Luton, Bedfordshire LU1 3LU, U.K.
Phone: +44-1582-433280
Fax: +44-1582-731303

- U.S.A.
ANRITSU COMPANY
1155 East Collins Boulevard,
Richardson, Texas 75081
Toll Free: 1-800-ANRITSU (267-4878)
Phone: +1-972-644-1777
Fax: +1-972-644-3416

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