



LXI in Satellite System Testing

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Agenda

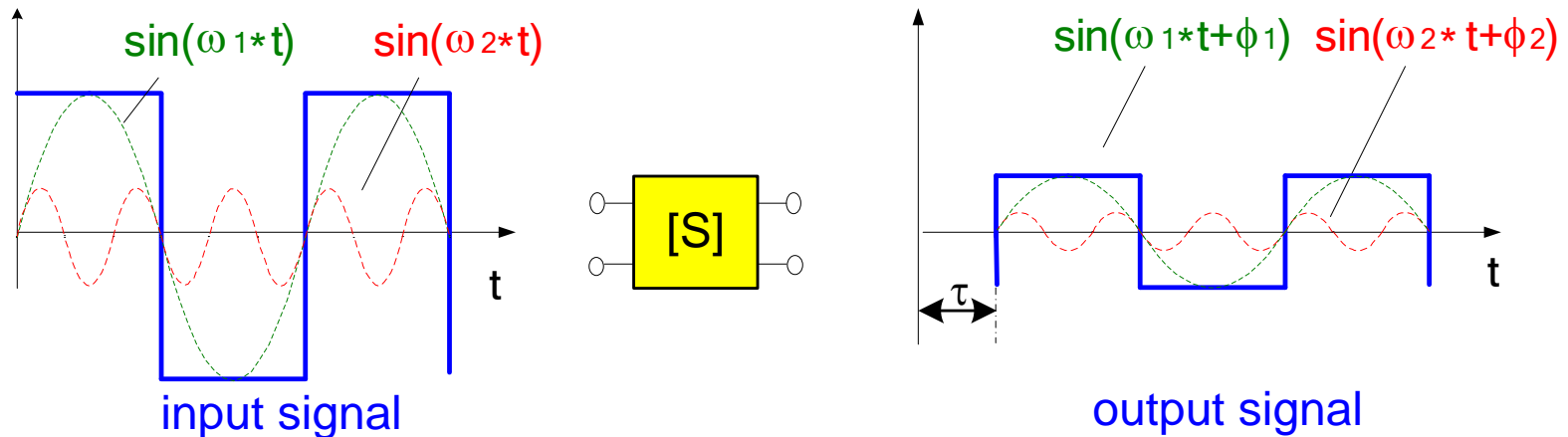
- **Microwave Communications Systems**
 - Phase Linearity and Group Delay
- **Two-Tone Method**
 - Quality of Transmission Systems
 - S-Parameters
 - Two-Tone Method
- **Group Delay Measurements with two LXI Network Analyzers**
 - System Setup and Configuration
 - LXI based Remote Configuration and Monitoring
 - LXI LAN Event Messages
 - Message and Control Flow
- **Summary**

Microwave Communication Systems



Satellite dishes at the Naval Computer and Telecommunications Area Master Station Pacific (NCTAMS)

Quality of Data Transmission



- **Constant attenuation for all spectral components within the transmission channel**
 - Characterized by conversion loss or magnitude of S_{21}
- **Identical time shift for all spectral components**

What does constant Time Shift mean

$$\varphi = -\omega \cdot \tau$$

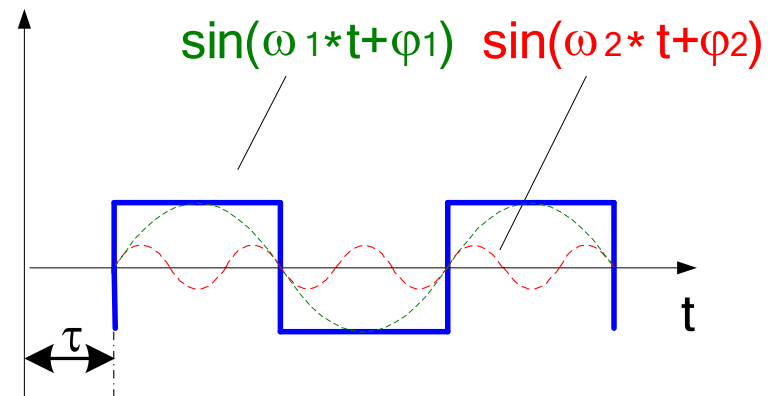
$$\varphi_1 = -\omega_1 \cdot \tau$$

$$\varphi_2 = -\omega_2 \cdot \tau$$

$$\varphi_2 - \varphi_1 = -\tau \cdot (\omega_2 - \omega_1)$$

$$-\frac{\Delta\varphi}{\Delta\omega} = \tau$$

with $\Delta\varphi = \varphi_2 - \varphi_1$ and $\Delta\omega = \omega_2 - \omega_1$

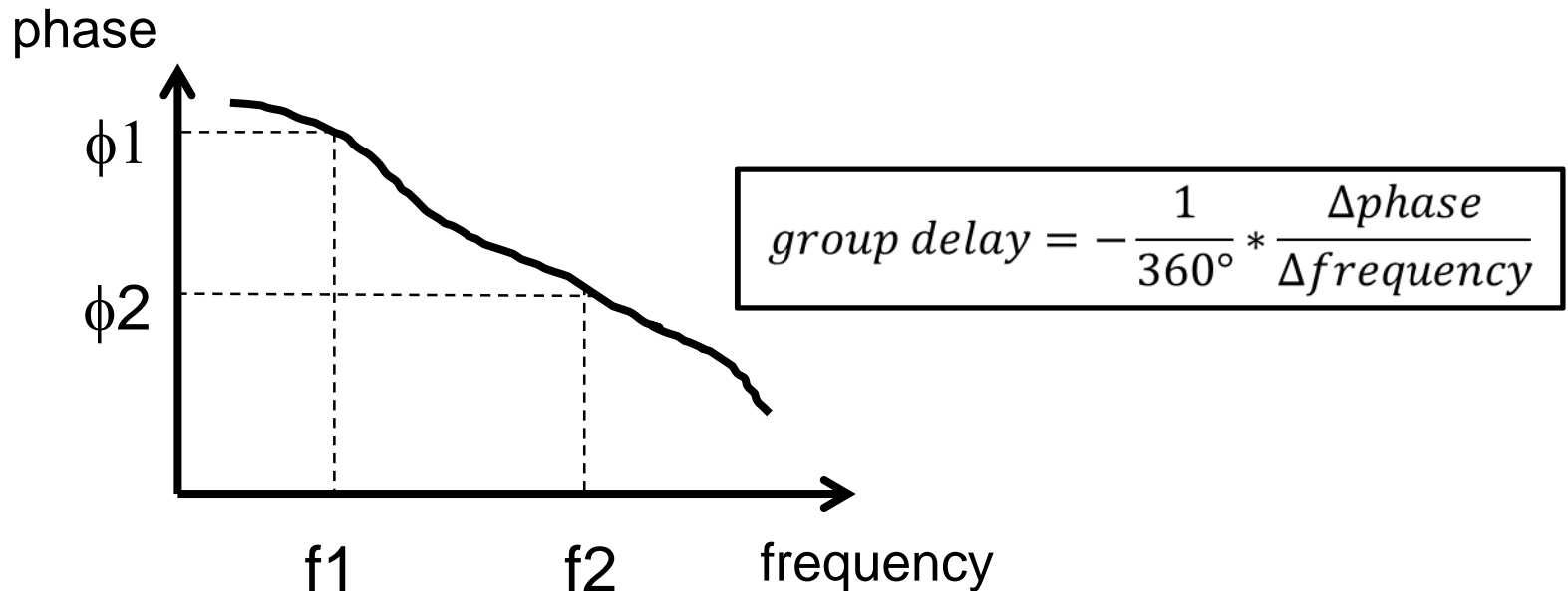


What does constant Time Shift mean?

- Phase of transmission parameter (S_{21} or conversion loss) must increase or decrease linearly with increasing frequencies
- Time shift or average signal transit time is the so-called group delay and is calculated as

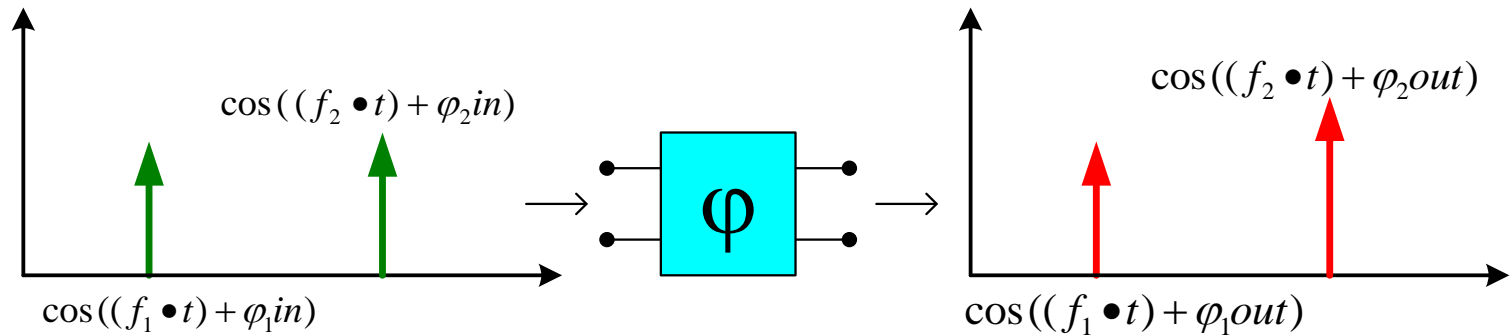
$$\tau = - \frac{1}{360^\circ} \bullet \frac{d\varphi}{df}$$

Definition of the Group Delay



- For non frequency converting DUT, the Group Delay can be calculated out of two S_{21} measurements
- For frequency converting DUTs, it's difficult because the input and output signals are at different frequencies

Solution – Two-Tone Method

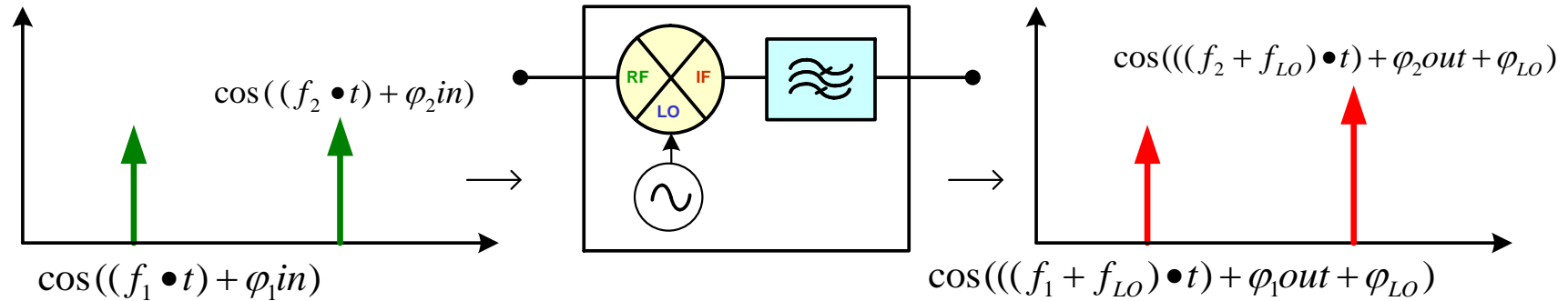


- Two signals at frequencies f_1 and f_2 injected into the DUT
- Phase shifts at the output due to the phase response of the DUT
- VNA measures phase differences at the input and the output

$$\Delta f = f_1 - f_2 \quad \Delta \varphi = (\varphi_{1out} - \varphi_{2out}) - (\varphi_{1in} - \varphi_{2in})$$

$$\tau = \frac{-1}{360^\circ} \cdot \frac{\Delta \varphi}{\Delta f}$$

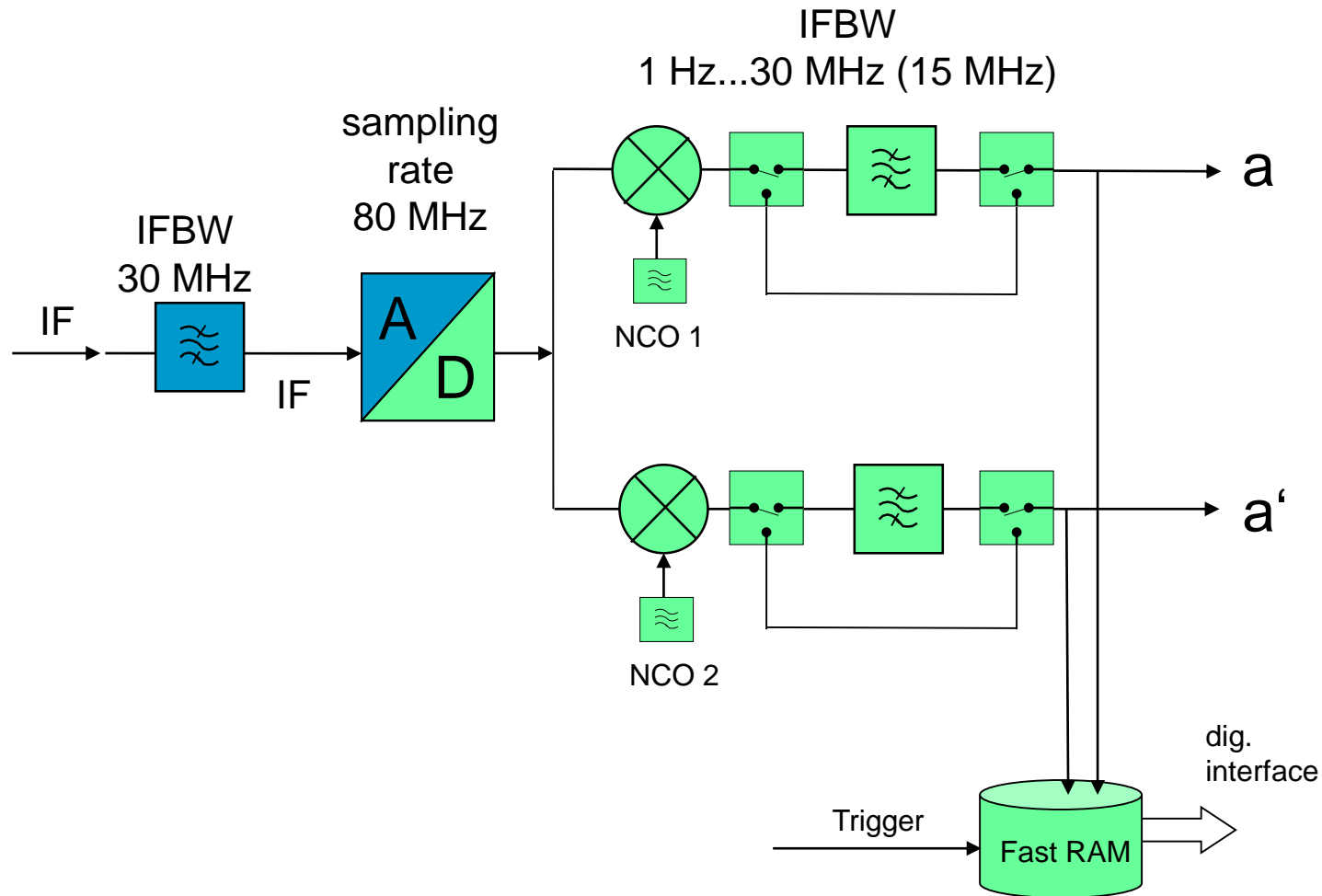
Measurement of a Converter



- An LO phase is added to φ_{1out} and φ_{2out} by same amount
- The difference of φ_{1out} and φ_{2out} is independent of the LO phase
 - LO phase and frequency shifts are cancelled out

$$\Delta\varphi = (\varphi_{1out} + \varphi_{LO} - \varphi_{2out} - \varphi_{LO}) - (\varphi_{1in} - \varphi_{2in})$$

Digital Dual Receiver Frontend of ZVA

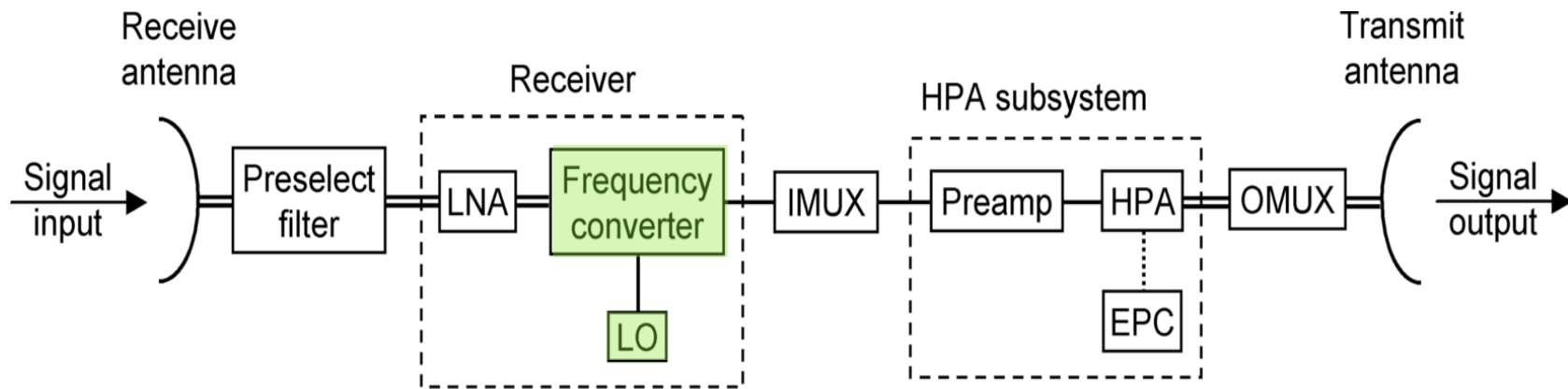


What is a Converter without LO Access ?

- Typically converters are used for up- and down-links of satellites or inside of satellites
- The LO is not accessible, often also the reference signal is not available
- Group delay is the key parameter for low bit error rate for data transmission



Block Diagram of a Satellite



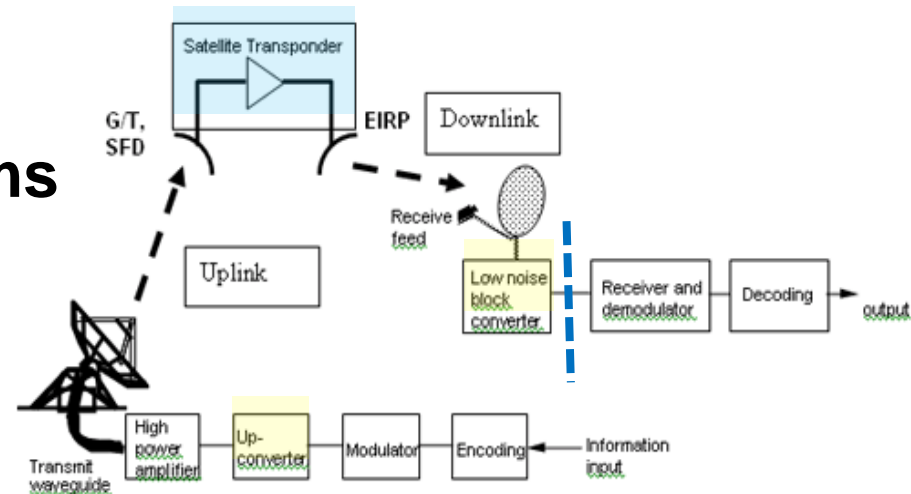
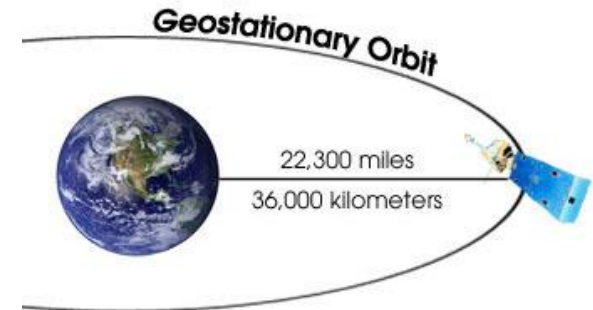
LNA = Low-noise amplifier
 LO = Local oscillator
 IMUX = Input multiplexer

== = Waveguide
 — = Coaxial cable

HPA = High-power amplifier
 EPC = Electronic power conditioner
 = Power supply
 OMUX = Output multiplexer

Measurement of Up and Down Link

- Transmission time of 120ms due to distance to earth
- Delay of 240ms between measurement of stimulus two tone signal and response signal
- Solution:
Trigger Delay of >240 ms



Group Delay Measurement with two VNAs installed at separate Locations

- **Problem:**
Measurement of group delay with long distance between input and output
- **Solution:**
Group Delay measurement with two separated LXI network analyzers (VNAs)
- Synchronization, triggering and transferring measurement results from slave to master instrument based on LXI Event Messages
- The master VNA acts as a controller and calculates and presents the required group delay measurement

Test Setup Procedure

- **Connect the instruments (LAN, Ext. Reference, RF)**



- **Find instruments on LAN with the LXI Discovery Tool**



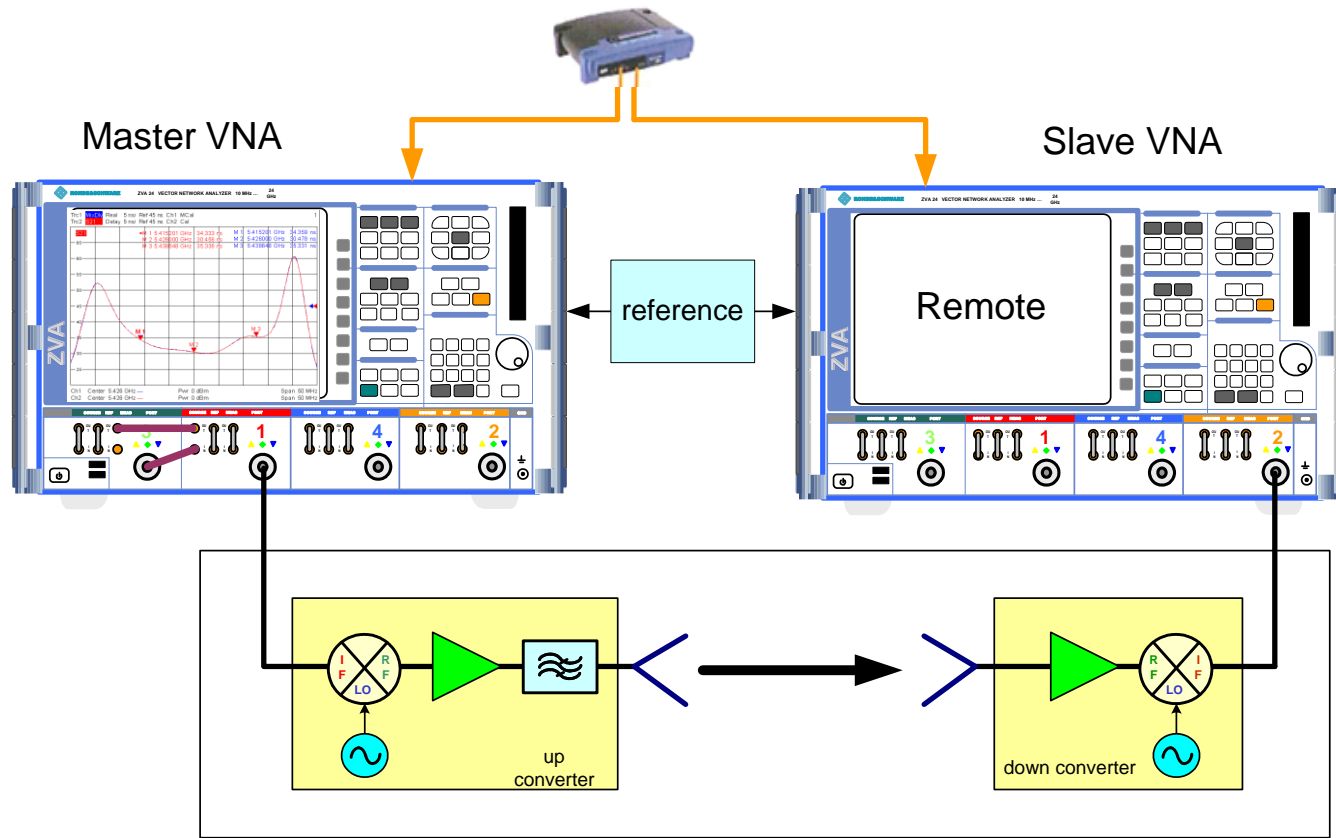
- **Configure remote slave VNA with LXI instrument web page**



- **Configure master VNA and start measurements**
- **Communication between master and slave VNA based on LXI peer-to-peer Event Messages**

Test Setup Procedure – Step 1

- Connect the instruments (LAN, Ext. Reference, RF):



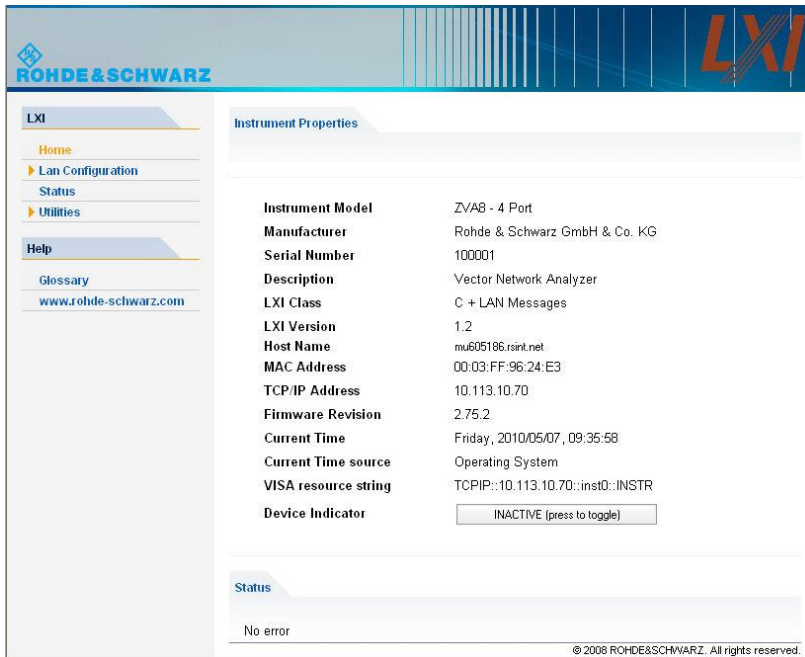
Test Setup Procedure – Step 2

- **Find instruments on LAN with the LXI Discovery Tool**
 - LXI Discovery Tool on an external controller attached to the LAN or
 - LXI Discovery Tool on the master VNA (Windows based)



Test Setup Procedure – Step 3

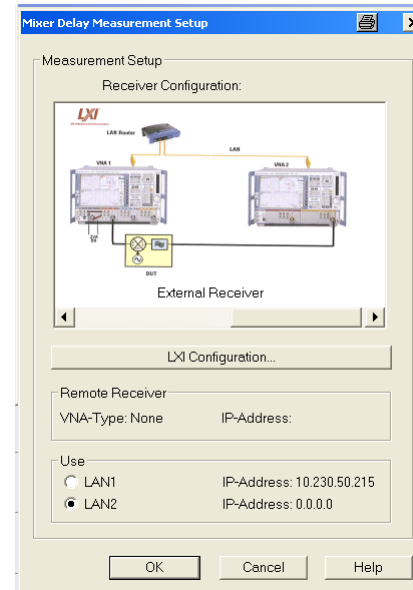
- **Configure remote slave VNA with LXI instrument web page**



The screenshot shows the LXI Instrument Properties web page. The page has a blue header with the Rohde & Schwarz logo and the LXI logo. A left sidebar contains navigation links: Home, Lan Configuration, Status, Utilities, Help, Glossary, and www.rohde-schwarz.com. The main content area is titled 'Instrument Properties' and displays the following information:

Instrument Model	ZVA8 - 4 Port
Manufacturer	Rohde & Schwarz GmbH & Co. KG
Serial Number	100001
Description	Vector Network Analyzer
LXI Class	C + LAN Messages
LXI Version	1.2
Host Name	mu605186.raink.net
MAC Address	00.03.FF.96.24.E3
TCP/IP Address	10.113.10.70
Firmware Revision	2.75.2
Current Time	Friday, 2010/05/07, 09:35:58
Current Time source	Operating System
VISA resource string	TCPIP::10.113.10.70::inst0::INSTR
Device Indicator	<input type="button" value="INACTIVE (press to toggle)"/>

At the bottom, there is a 'Status' section showing 'No error' and a copyright notice: © 2008 ROHDE&SCHWARZ. All rights reserved.



The screenshot shows the 'Mixer Delay Measurement Setup' dialog box. It features a 'Measurement Setup' section with a 'Receiver Configuration' diagram. The diagram illustrates two VNAs connected via LAN, with an external receiver connected to VNA 2. Below the diagram is an 'External Receiver' label and a scroll bar. The dialog also includes an 'LXI Configuration...' button and a 'Remote Receiver' section with the following fields:

VNA-Type:	None	IP-Address:	
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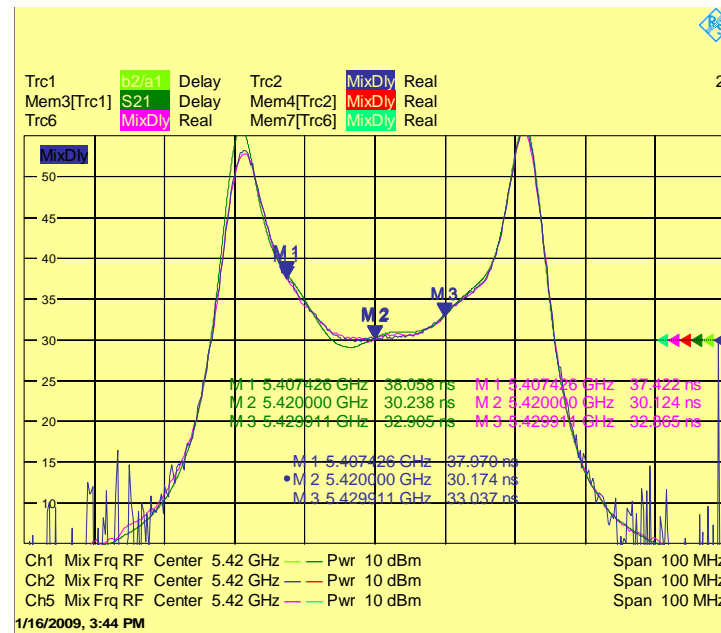
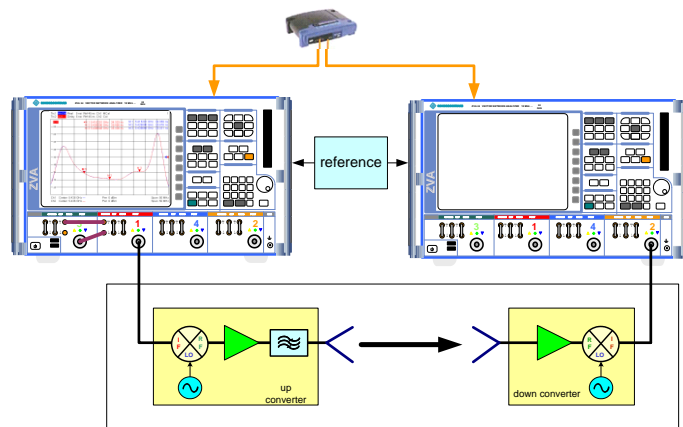
Below this is a 'Use' section with two radio button options:

<input type="radio"/> LAN1	IP-Address: 10.230.50.215
<input checked="" type="radio"/> LAN2	IP-Address: 0.0.0.0

At the bottom of the dialog are 'OK', 'Cancel', and 'Help' buttons.

Test Setup Procedure – Step 4


- Configure master VNA and start measurements
- Communication between master and slave VNA based on LXI peer-to-peer Event Messages



LXI Event Messages

- **LXI Event Message Format:**

HW Detect	Domain	Event ID	Sequence	Timestamp	Epoch	Flags	Data Fields...	0 (two bytes)
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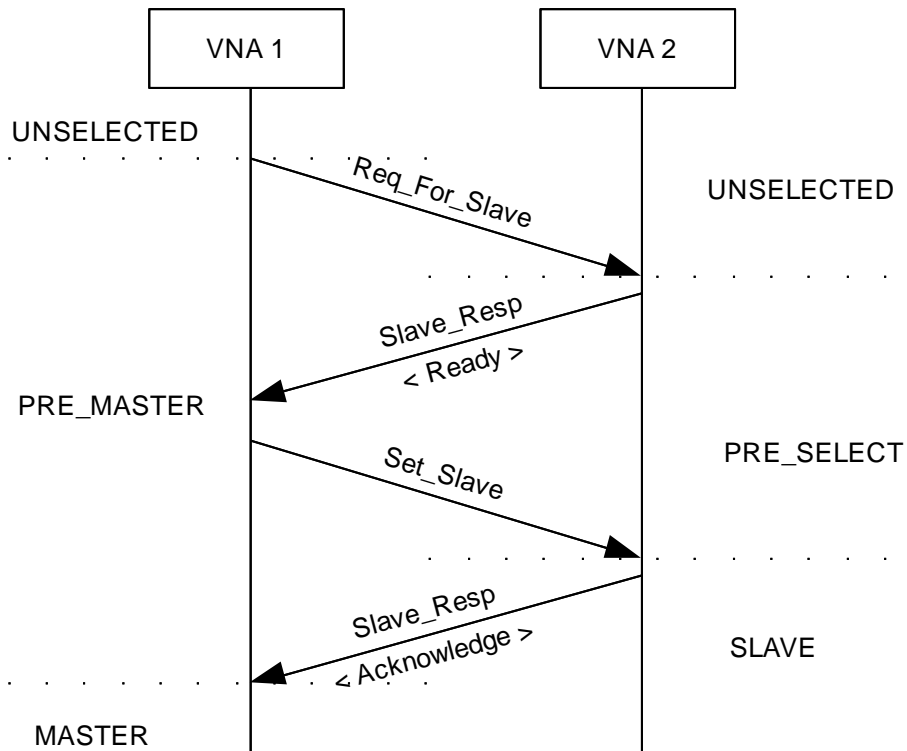
- **Multicast via UDP or peer-to-peer communication via TCP/IP**
- **Each message is time stamped**
- **Data format flexible (ASCII, float, XML, ...)**

Message and Control Flow

- **Group Delay Measurement based on LXI message communication between master VNA and slave VNA**
- **Master VNA:**
 - Generates two-tone signal
 - Manages the data handling
 - Calculates and displays the measurement results
- **Slave VNA:**
 - Measures the phase difference between the two tones
 - Sends the measurement data to the master VNA

Sequence Flow Diagram

- **Master-slave Negotiation Sequence**





LAN eXtensions for Instrumentation

Summary

- **LXI is the preferred solution for distributed systems, e.g. group delay measurements on converters w/o LO access**
- **LXI allows to discover instruments on the LAN and to configure them via the web interface**
- **Peer-to-peer communication between LXI instruments simplifies the test system software (or even enables applications w/o controller)**

