Vector Network Analysis
A view at classical measurements used in new applications

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Agenda

- What is a Vector Network Analyzer?
- Network Analyzer Measurements Basics
- Innovative New Applications for VNAs

What is a Vector Network Analyzer?

- Vector Network Analyzers measure
  - the magnitude and phase characteristics of
  - networks, amplifiers, components, cables, and antennas

- They compare the incident signal that leaves the analyzer with
  - either the signal that is transmitted through the test device or
  - the signal that is reflected from its input.

What is a Vector Network Analyzer?

- Figure 1 and Figure 2 illustrate the types of measurements that the Anritsu VNA performs

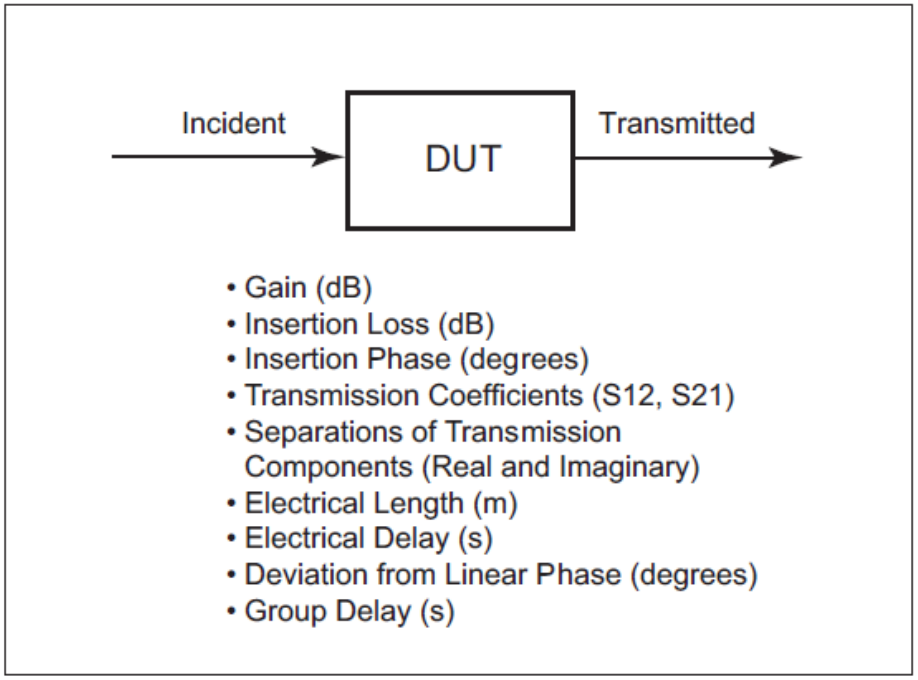


Figure 1. Transmission Measurements

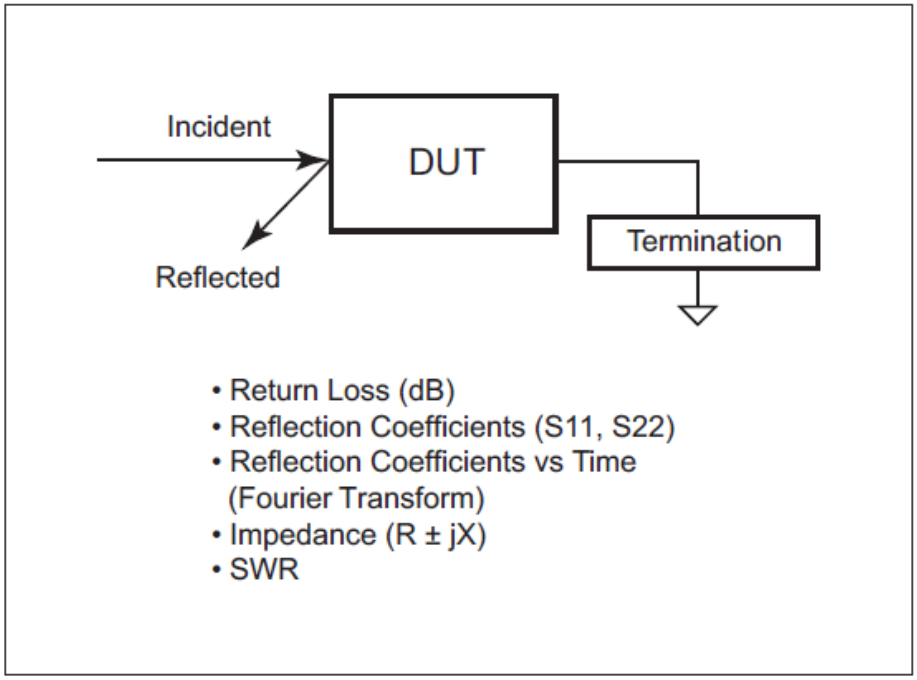


Figure 2. Reflection Measurements

What is a Vector Network Analyzer?

- VNAs are self contained, fully integrated measurement systems that include an optional time domain capability.

- The system hardware typcially consists of the following:
  - Analyzer
  - Precision components required for calibration and performance verification

Network Analyzer Measurements Basics

- Now let us consider measuring the DUT, a two port device with a connector on each end. What measurements would be of interest?

- Reflection characteristics at either end with the opposite end terminated into 50 ohms. If we designate one of the inputs as Port 1 of the device, then we have a reference port. We can then define the reflection characteristics from the reference end as forward reflection, and those from the other end as reverse reflection (Figure 14).

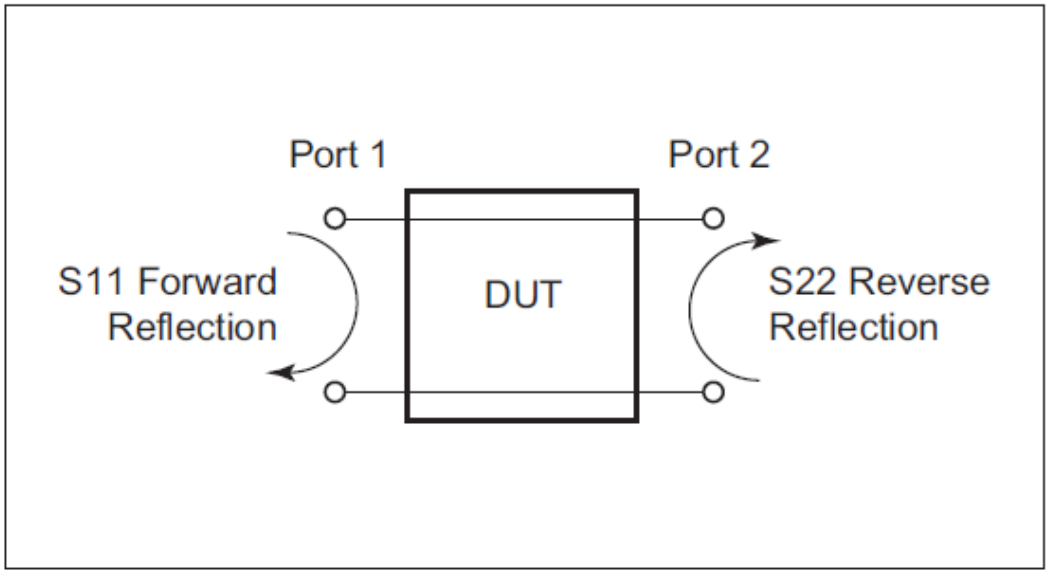


Figure 14. Forward and Reverse Measurements

Network Analyzer Measurements Basics

- Forward and reverse transmission characteristics. However, instead of saying “forward,” “reverse,” “reflection,” and “transmission” all the time, we use a shorthand – the “S” under S-parameters stands for scattering.

- The second number is the device port that the signal is being injected into, while the first is the device port that the signal is leaving. S11, therefore, is the signal leaving port 1 relative to the signal injected into port 1. The four scattering parameters (Figure 15) are:

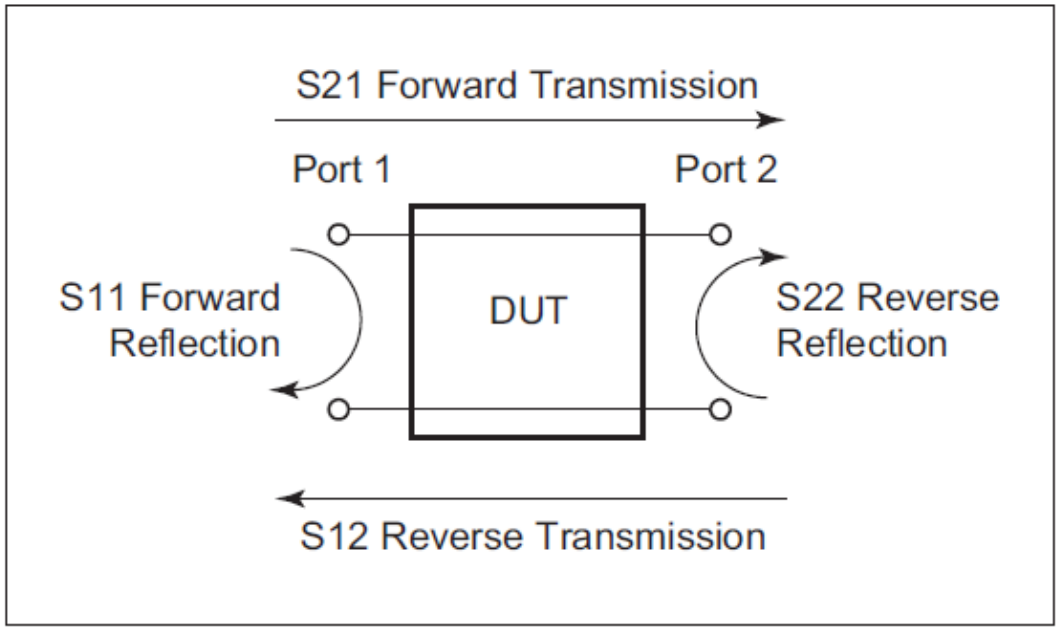


Figure 15. S-Parameters

What do we test with a VNA and why?

- A classical application for VNAs is the testing of components, which are used as “building blocks” in more complicated RF systems. For example, this could be amplifiers to boost power, but also filters to remove signal harmonics in communication system.

- Target is to ensure low level distrotion / distortionless transmission of communication signals
  - liner, i.e. constant amplitude, linear phase / constant group delay, ..
  - non-linear, i.e. Harmonics, intermodulation, compression, ...

- Ensure good match when absorbing power (i.e. an antenna)

Innovative New Applications for VNAs - Medical

- Routine checks for early detection of breast cancer are becoming more and more wide-spread, though a limiting factor is the cost of such system.

- Microwave frequencies are being investigated for breast tumour detection, having the benefit that it is a non-invasive technique that uses non ionizing radiation.

- Microwave imaging has the potential to achieve early detection of breast cancer due to the high specificity and the large difference in electrical properties of the malignant tissue when compared to normal breast tissue

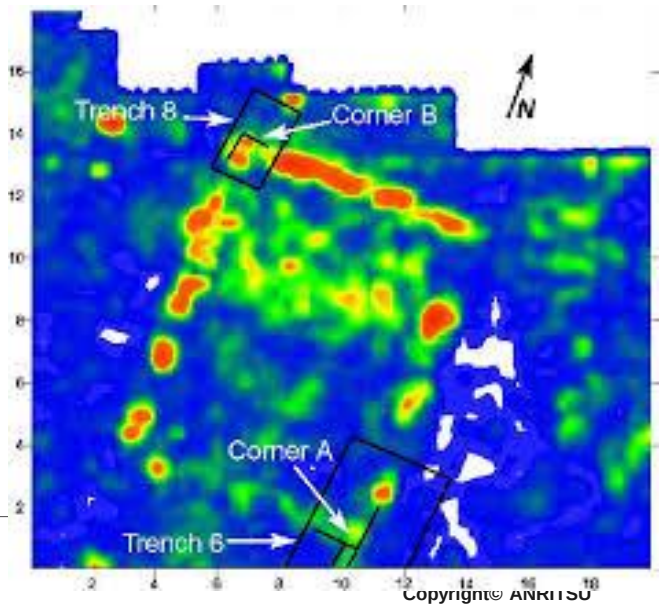
- Proof was shown in prototype systems that using
  - Vector Network Analyzer Hardware for reflection measurements
  - and 3D imaging SW
  - at frequencies as low as 8GHz
- irregularities in soft tissue can be detected with very high accuracy

Innovative New Applications for VNAs - Archeology

- Consider ground penetrating radars, that are used to find man-built structurs burried underground, used for archeological purposes.

- Same can be achieved using
  - a VNA as a main HW part of a system that is installed in an aircraft / car / etc
  - transmit & receive antennas that will allow measuring the reflection charactieristics o
  - a SW that calculates a 3D picture of ground / hidden underground structures based on VNA reflection characteristics measurement

Similar to a GPR, but VNA can cut costs strongly!

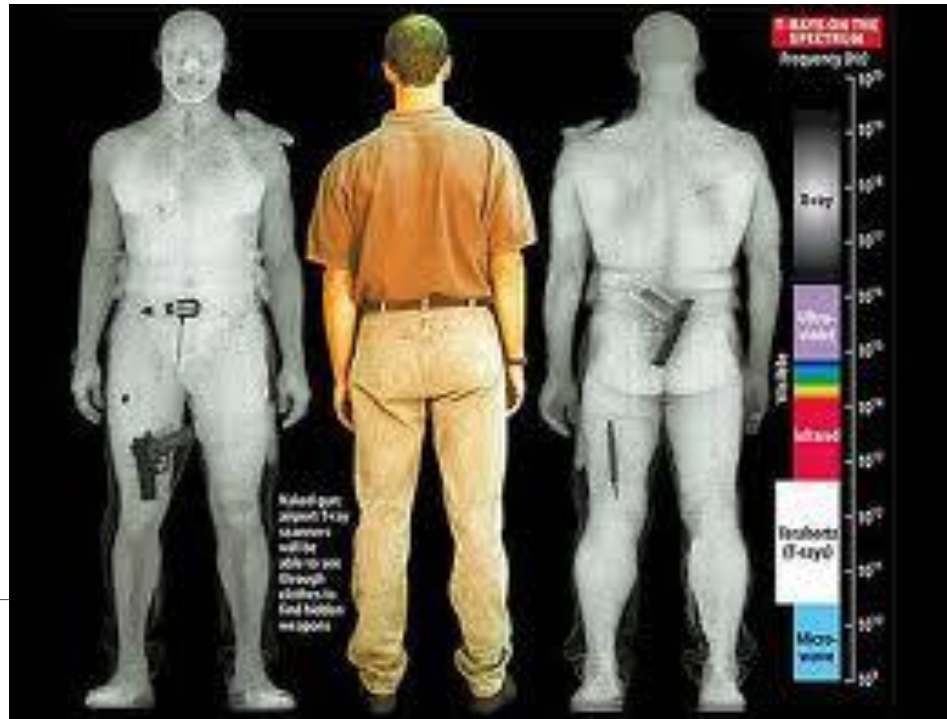


Innovative New Applications for VNAs - Airport Security

- Have you ever wondered how the famous airport body scanners are working, which allow to detect metal parts on your body / hidden for the eyes in your clothes?

- It is all about doing a reflection measurement – so essentially again
  - a VNA as the HW component plus
  - imaging SW that is converting the mesurement results to a 3D picture of your body

- i.e. items made out of metal offer significantly higher reflection than the soft tissue of your body, which is the way how these systems can accurately show even the tinies speck of metal on your body



Innovative New Applications for VNAs - Avalanche Prediction

- Ever seens somebody up on a mountain in winter time, pushing 2 probes into the snow and staring at a portable electronic device or a Laptop screen?

- If so, you might have wintessed usage of a GPR (Ground Penetrating Radar) or a VNA in the field for avalanche prediction.

- The concept is the same as mentioned in previous slides
  - the probes basically act like antennas, sending out signals / receiving signals
  - the VNA measures the transmitted / reflected power of the snow
  - imaging Software allows displaying differences in the crystaline structures in the snow / ice, allowing for a more accurate prediction of danger of avalanches

Innovative New Applications for VNAs – „to bee or not to bee“

- In what must surely be one of the most innovative uses of a vector network analyser (VNA), a team of research scientists deployed an Anritsu VectorStar™ VNA to track the movements of migratory bees.

- Scientists from the Psychology Division at Queen Mary College London and the Harmonic Radar Group at Rothamsted Research in Harpenden, just down the road from Anritsu’s UK HQ, used radar, motion-triggered webcams, and tiny radar transponders attached to bumblebees to track them as they flew to artificial flowers.

- Each flower featured a drop of sucrose to attract the insects. Researchers tracked the sequence of flower visits made on each foraging outing by the bees. They discovered that bumblebees chose the closest flowers first and added new flowers during subsequent outings.

Innovative New Applications for VNAs – „to bee or not to bee“

- Vertical-looking radar (VLR) monitored migratory bee movements at high altitude, while harmonic radar recorded the flight paths of low-flying insects.

- Harmonic radar also tracked the flight of bees that had attended a ‘waggle dance’, where a returning foraging bee communicates to others back at the hive. Armed with the location information of productive (artificial) flowers, these bumblebees flew straight to the vicinity of the feeding site, as predicted by Nobel Prize winning zoologist Karl von Frisch.

- The tracks allowed the scientists to determine how accurately bees translate the dance code into successful navigation, and showed that they correct for wind drift even when flying to destinations they have never visited before.

Many thanks for your attention!

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