Drivers beyond the millimeter Wave frequency race

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Keysight Technologies

RF 2018 TECHNOLOGY DAYS

DE BASILIEK
VEENENDAAL
18 APRIL 2018

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KEYSIGHT TECHNOLOGIES

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Agenda

Introduction & Agenda

Why mmWave

Industry needs & mmWave challenges

Generating mmWAve

Analyzing mmWave

Characterizing mmWave components

Summary & conclusion

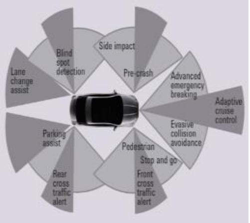
Why Millimeter Wave

TRENDS

Massive Growth in Mobile Data Demand

Exploding Diversity of Wireless Applications

Need of fast (faster..) data transmission rate

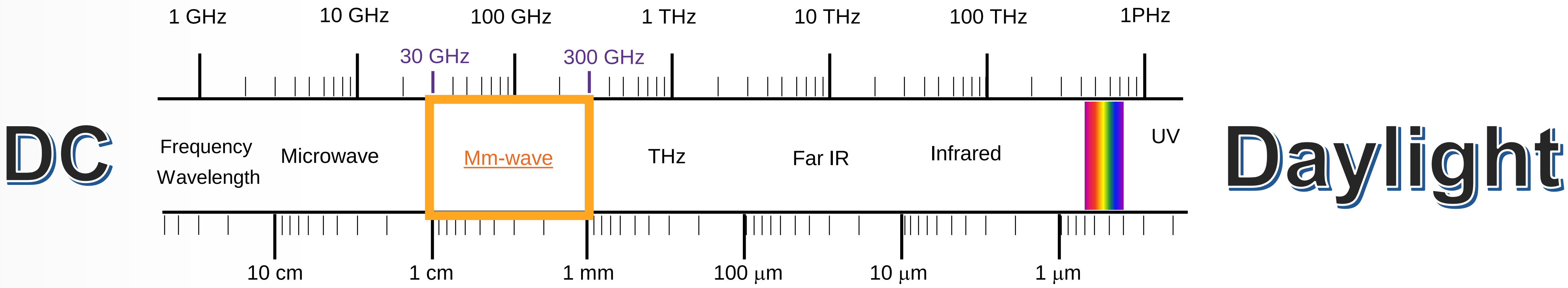


Expansion of sensors/transducers working in a dense environment

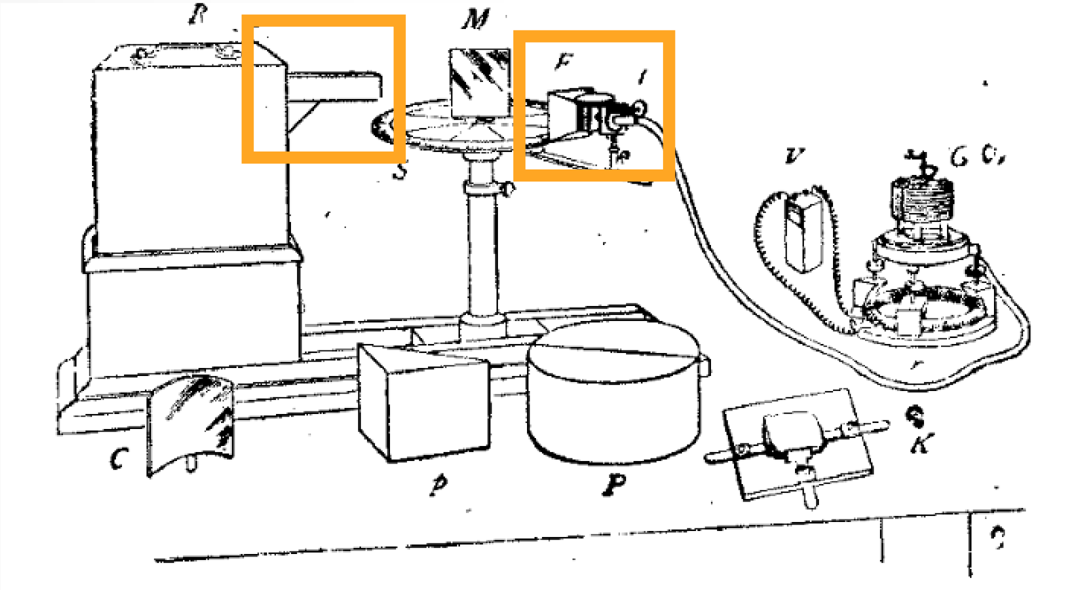
Massive Growth
in Number of Connected Devices

Increase of unwanted interference

What is Millimeter wave ?

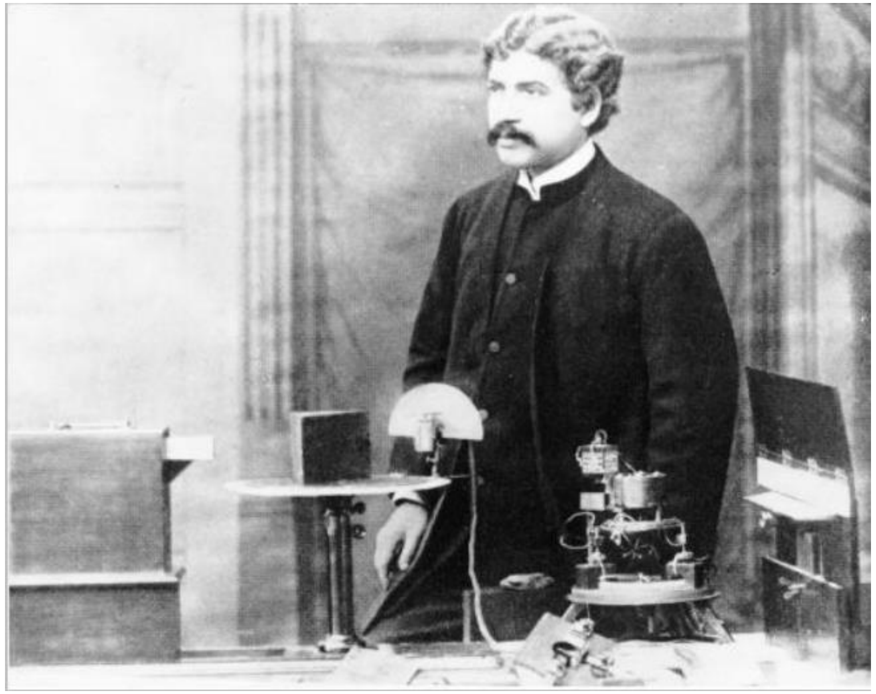


Millimeter Wave setup in 1897



R, radiator ; S, spectrometer-circle ; M, plane mirror ; C, cylindrical mirror ; p, totally reflecting prism ; P, semi-cylinders ; K, crystal-holder ; F, collecting funnel attached to the spiral spring receiver ; t, tangent screw, by which the receiver is rotated ; V, voltaic cell ; r, circular rheostat ; G, galvanometer.

Bose's apparatus demonstrated to the Royal Institution in London in 1897 [2]



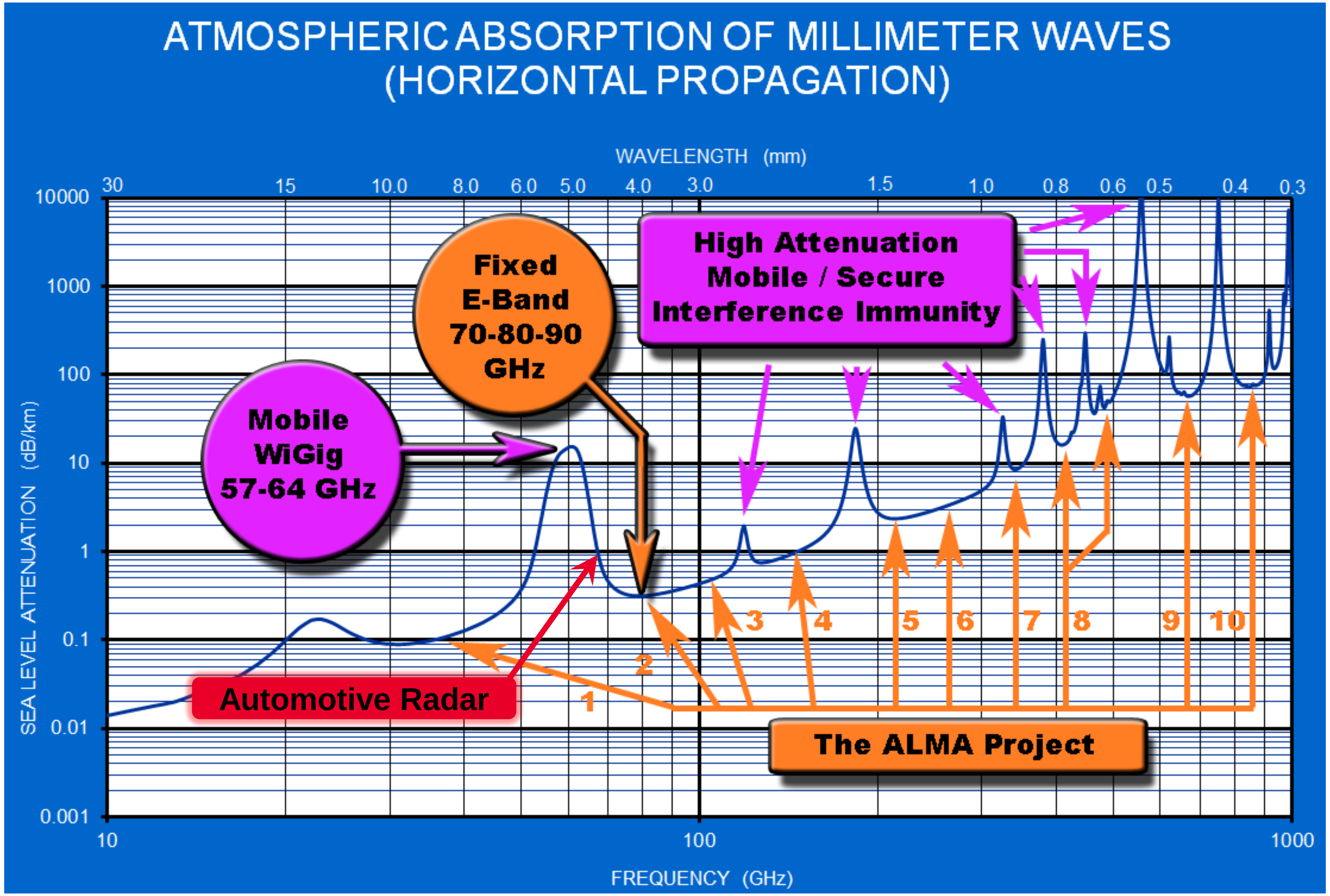
J.C. Bose at the Royal Institution, London, 1897. [1]

[1] **Photograph from *Acharya Jagadis Chandra Bose, Birth Centenary, 1858-1958*. Calcutta: published by the Birth Centenary Committee, printed by P.C. Ray, November 1958**
[2] J.C. Bose, Collected Physical Papers. New York, N.Y.: Longmans, Green and Co., 1927.

What are the benefits of Millimeter waves ?

- Wide “Free” Bandwidth Available
- Small components sizes (antennas, transmitters….)
- High Free space attenuation that causes low interferences
- Advantageous use of atmospheric properties

Millimeter Wave & Atmospheric Properties



Emerging millimeter Wave Applications

- Automotive Radar
- Early next-generation wireless (“5G”)
- 802.11ad WiGig
- Aerospace/Defense
  - Radar & EW
  - Secure Communication systems
  - Airport Security
- Backhaul radio systems

© 2010 Wireless Gigabit Alliance

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Millimeter Wave serves industry needs (industry drivers)

Wireless (5G)

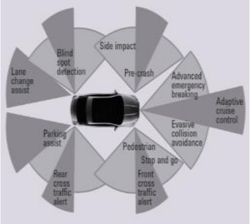
Massive Growth in Mobile Data Demand

Need of fast (faster..) data transmission rate

Massive Growth
in Number of Connected Devices

Radar/Sensor

Exploding Diversity of Wireless Applications



Expansion of sensors/transducers working in dense environment

Increase of unwanted interference

mmWave challenges

INDUSTRY NEEDS TRANSLATE INTO MMWAVE CHALLENGES

- Generate and analyze high-quality wideband mmWave signals with low spurious contents
- Detect a very small mmWave signal in a accurate way
- Generate & detect these signals in the presence of “other” signals
- Characterize these to be used mmWave components with metrology grade accuracy

Example: Wireless Industry Need & small mmWave signal

NEED SMALL CELLS FOR GREAT SERVICE IN A CROWD

Wireless

Massive Growth in Number of Connected Devices

mmWave signals attenuate quickly with distance
mmWave small cells enable dense deployment

Emerging 92–95 GHz small cell point-to-point backhaul

Emissions measurement in 86-92 GHz passive band (Astronomy)

Design and measurement challenges

Small signal strength

- Very small signals in more noise as frequency/bandwidth increases

Main challenge

Being able to detect very small signal in a accurate way.

Example: Radar/Sensors Industry Need & “Other signals”

INTEROPERABILITY CHALLENGES

Radar/Sensors

Exploding Diversity of Wireless Applications

Increase of unwanted interference

RF & Microwave are everywhere

Design and measurement challenges

Bandwidth and interference management

- Compliance/interoperability vs. existing bands
- EMC (Electromagnetic compatibility) effect to taken care of

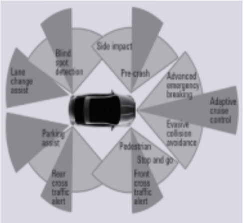
Main challenge

Being able to generate & detect signals in the presence of “other” signals.

Generic mmWave Industry Needs

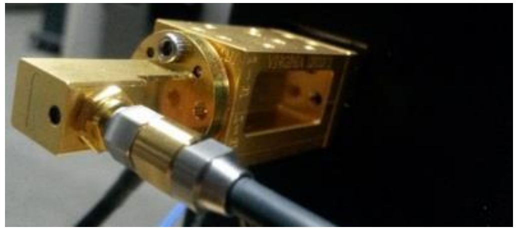
SMALLER WAVELENGTHS, SMALLER COMPONENTS

Massive Growth in Number of Connected Devices



Compact, Mobile Platforms

High frequency leads to smaller components



Design and measurement challenges

Small dimensions & complex test setups

- Smaller, fragile cables, adaptors; calibration, stability
- Ultra wideband frequency spans, more spurs and noise
- More difficult to maintain the same transmission performance at mm-Wave

Main challenge

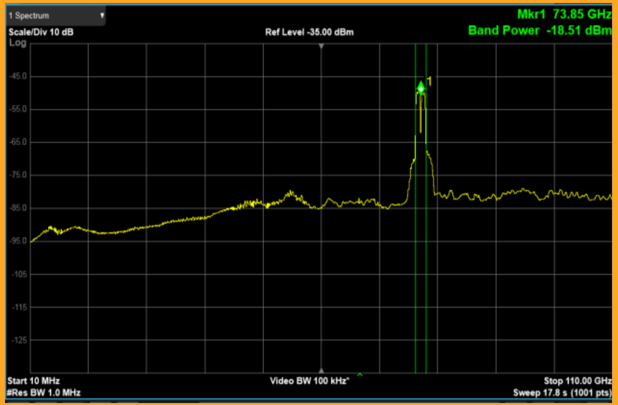
Being able to characterize components at very high frequency with metrology grade accuracy.

Design & Measurement Challenges at Millimeter Wave

CREATED BY THE INDUSTRY MOVING TO MILLIMETER WAVE

Generate quality millimeter wave wideband signal with low spurious contents

Analyze low strength wideband millimeter wave signals



Characterize components at very high frequency with metrology grade accuracy

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Millimeter Signal Generation

<u>Methods of generating mm-wave signals</u>

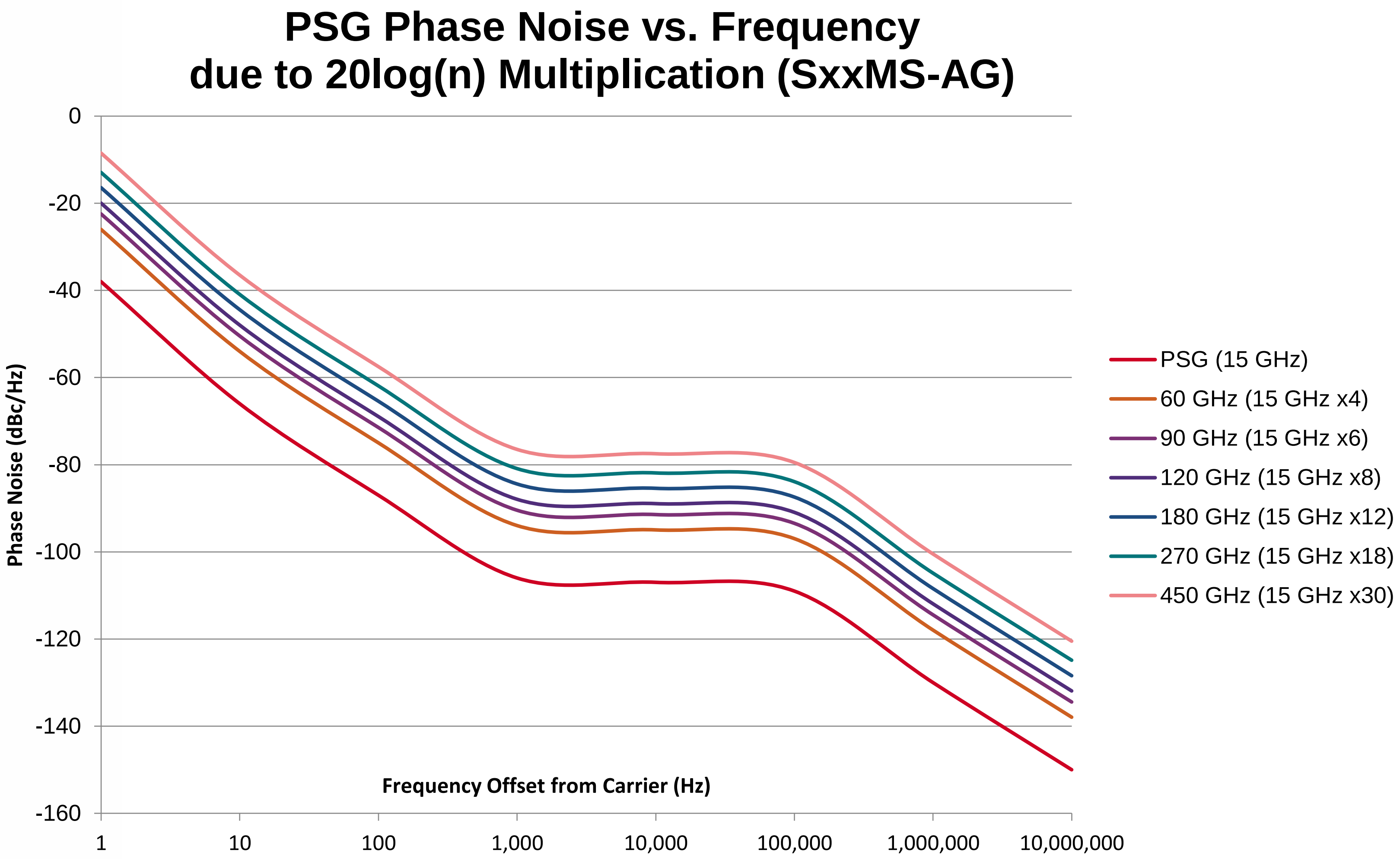
- Multiplication
- Upconversion

<u>Considerations</u>

- Frequency range requirements
- Output power requirements
- Modulation and Bandwidth requirements
- Minimizing spurious signals

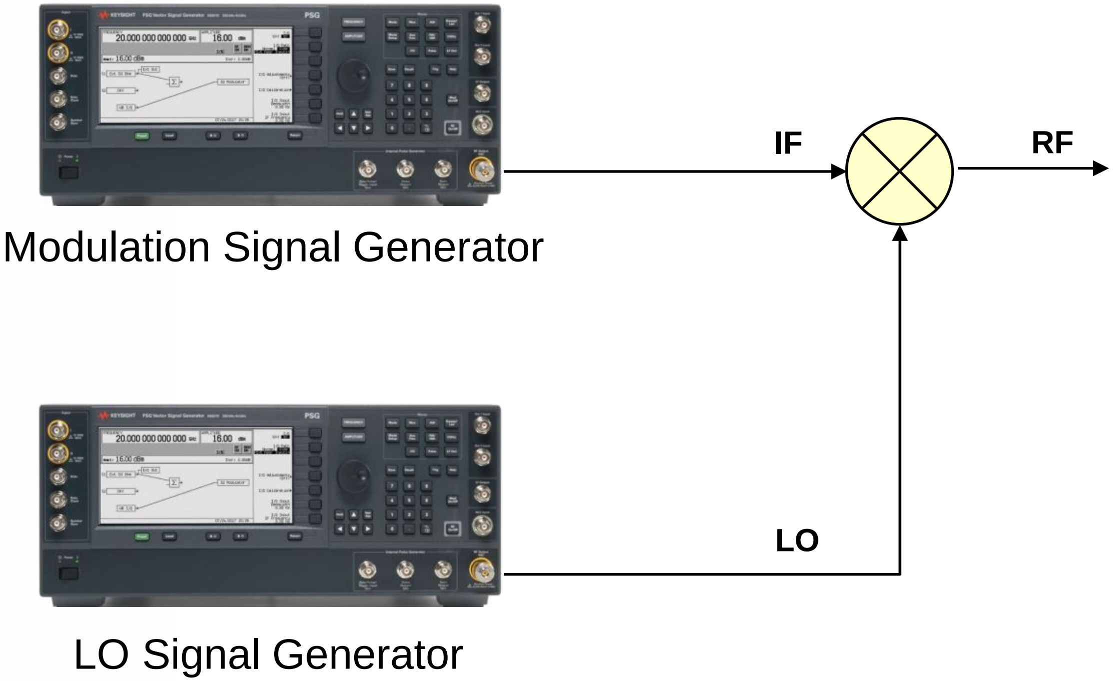
Signal Multiplication & Phase Noise

2X MULTIPLICATION INCREASES PHASE NOISE BY 6 DB



Signal Generation: Upconverting

UP-CONVERTING A MICROWAVE SIGNAL TO ACHIEVE MILLIMETER FREQUENCIES



$$F_{RF} = F_{LO} \pm F_{IF}$$

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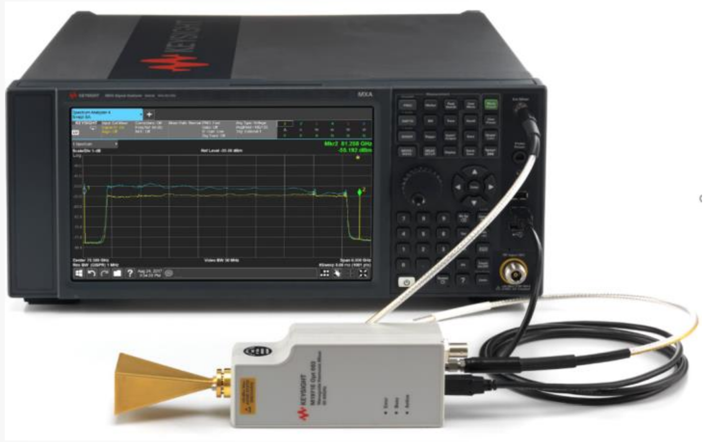
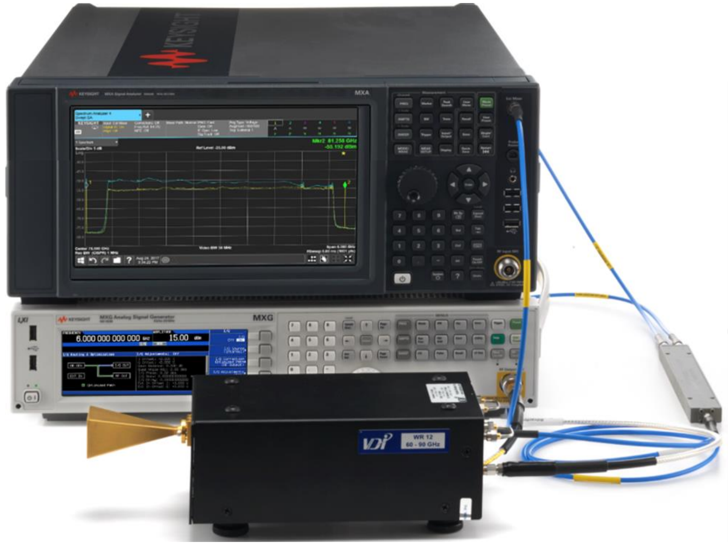
Millimeter Signal Analysis

Harmonic mixing



Fundamental mixing



Low loss millimeter front-end

<u>Methods of analyzing mm-wave signals</u>

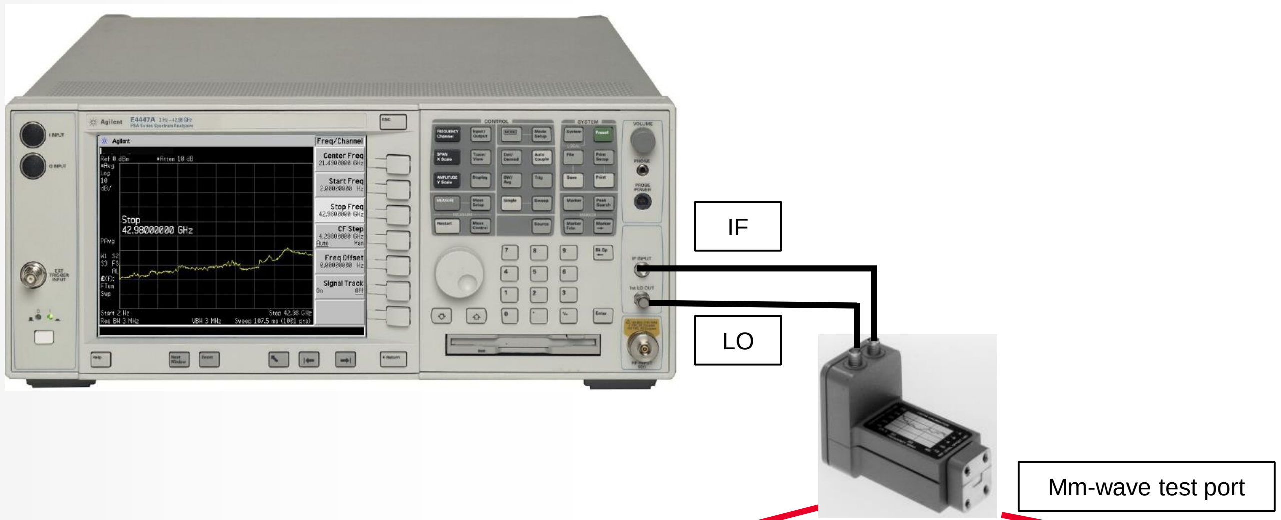
- Harmonic mixing
- Fundamental mixing
- Low loss millimeter front-end

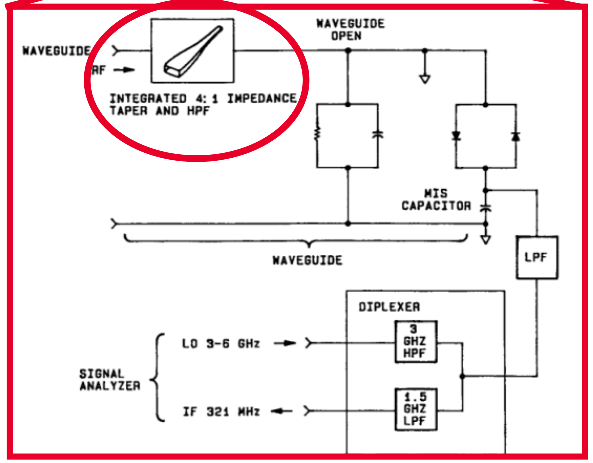
<u>Considerations</u>

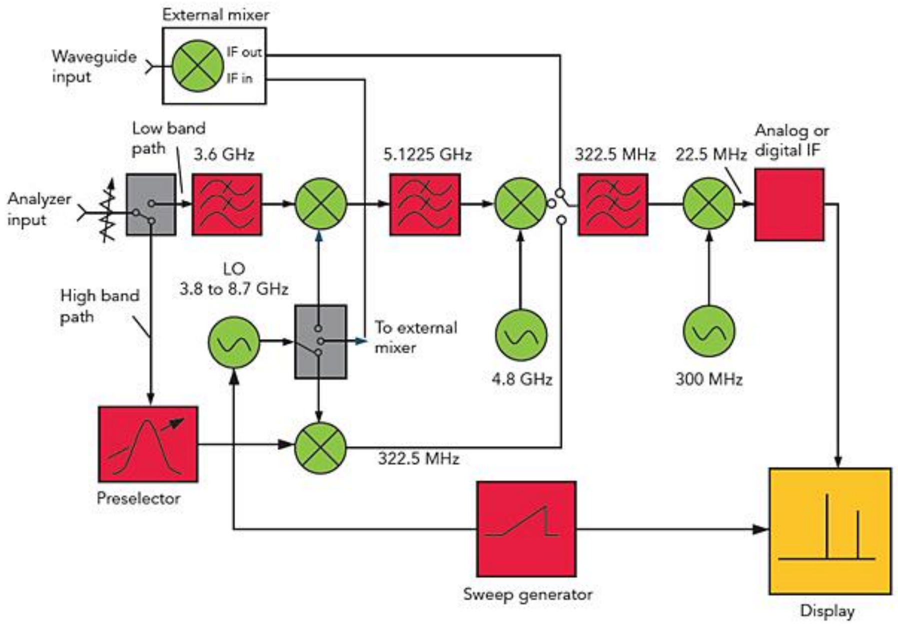
- Frequency range requirements
- Conversion loss and sensitivity requirements
- Modulation and Bandwidth requirements
- Minimizing spurious signals

Millimeter Signal Analysis: Harmonic Mixing

USING A HARMONIC MIXER TO EXTEND THE SPECTRUM ANALYZER FREQUENCY RANGE.



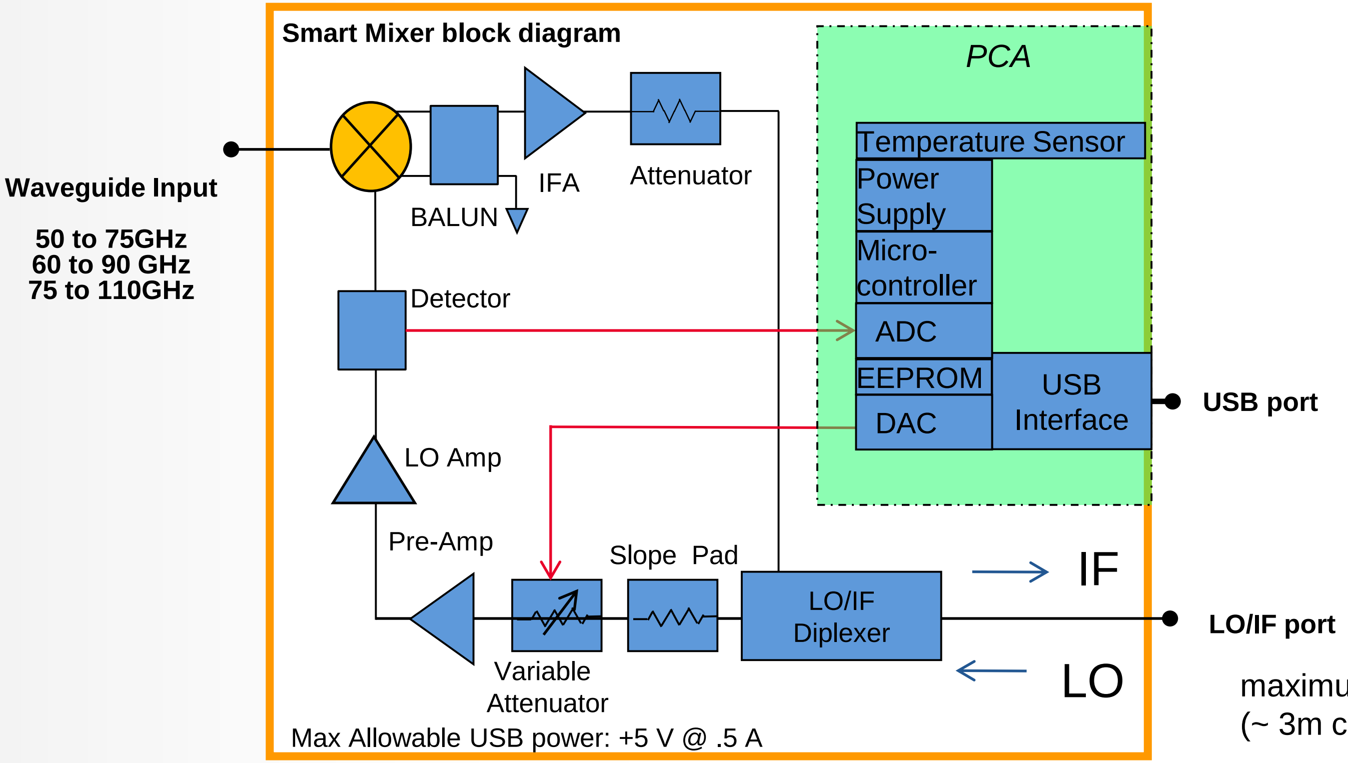


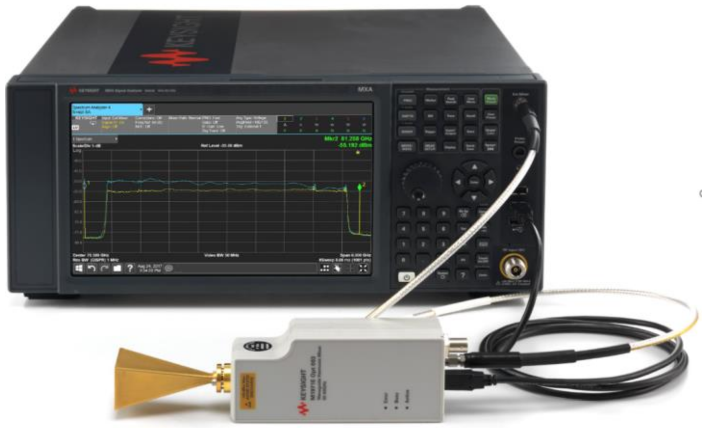


Harmonic mixing = use a harmonic of the original LO signal.
90 GHz = 18th harmonic of 5 GHz
www.literature.cdn.keysight.com/litweb/pdf/11970-90040.pdf
pages 69-70 for detailed harmonic mixer circuit description

Millimeter Signal Analysis: Harmonic Mixing

USING A HARMONIC MIXER TO EXTEND THE SPECTRUM ANALYZER FREQUENCY RANGE





maximum up to 10dB loss
(~ 3m cable length)

- Constant, leveled, LO power
- Amplitude & phase corrected

Millimeter Signal Analysis: mmWave Spectrum Analyzer

USING A LOW LOSS MILLIMETER FRONT-END INSIDE THE SPECTRUM ANALYZER

3 Hz - **110 GHz** Continuous sweeps

5 GHz BW

-150 dBm/Hz DANL
up to 110 GHz

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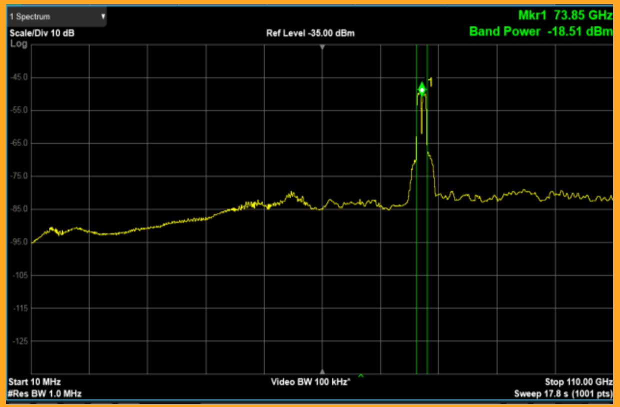
Characterizing mmWave Components

FILTERS, AMPLIFIERS, MIXERS

Generate quality millimeter wave wideband signal with low spurious contents

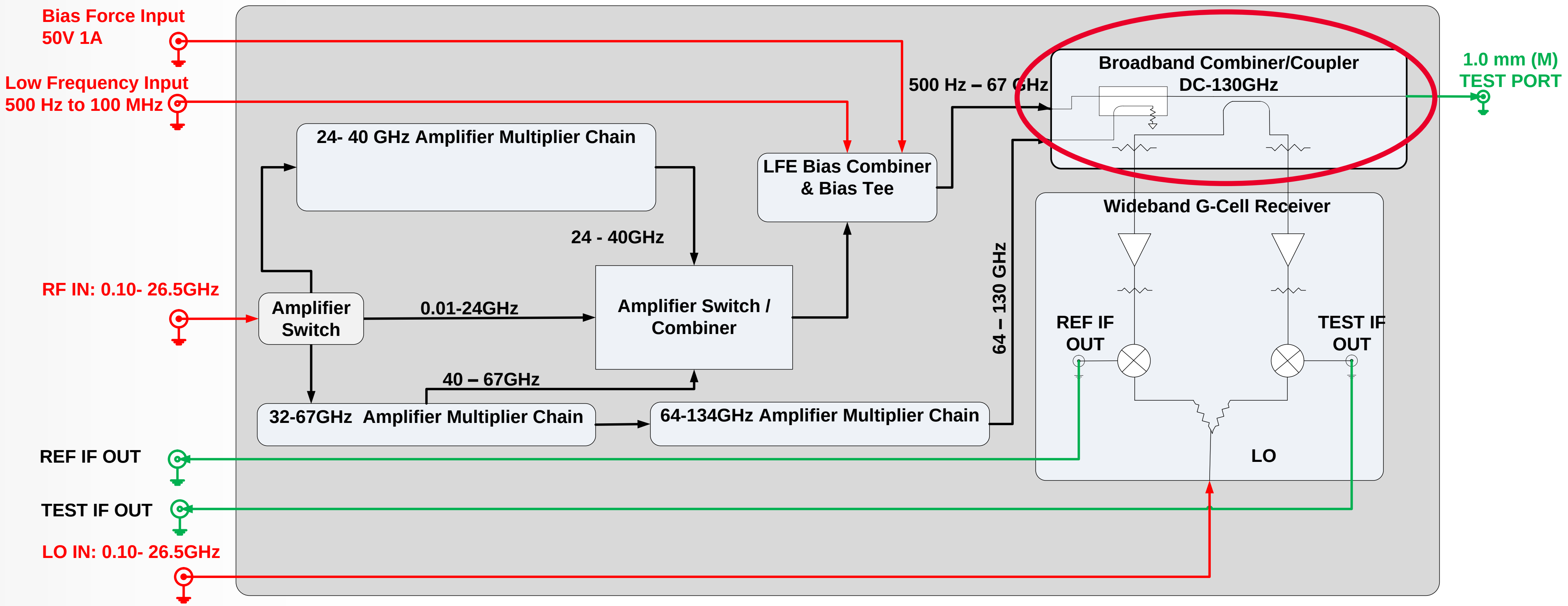
Analyze low strength wideband millimeter wave signals



Characterize components at very high frequency with metrology grade accuracy

Frequency Extender Module

EXTENDING NETWORK ANALYZER TO MMWAVE FREQUENCIES



Implementation for Broadband 500 Hz up to 130 GHz Frequency Coverage

Passive Device Characterization

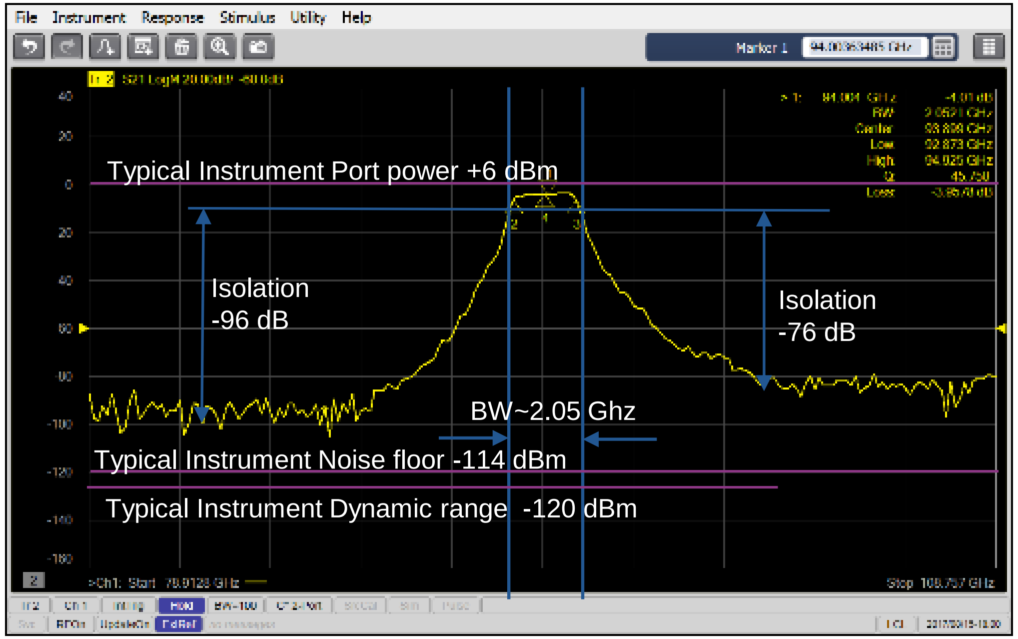
RECEIVER 93 GHZ BANDPASS FILTER CHARACTERISTICS

- Measurement System Capability
  - Accurate S-Parameter Calibration
  - Dynamic range
  - Noise floor / isolation
  - Trace noise

- Measurement Requirements
  - Filter Bandwidth
  - Filter rejection
  - Match in passband

Passive Device Characterization: Filter Example

93 GHZ BAND-PASS FILTER MEASUREMENT RESULTS



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Conclusions and thoughts: The Next Ten Years

- Today: immediate availability of data, always and everywhere
  - fixed and mobile computing devices with high data bandwidth
  - cloud storage with large-capacity data centers, network access
  - broadband wired and wireless networks

- Tomorrow: the interconnection of people and things
  - but both people and machines create and consume data
  - the ‘ Internet of Things’ (IoT)

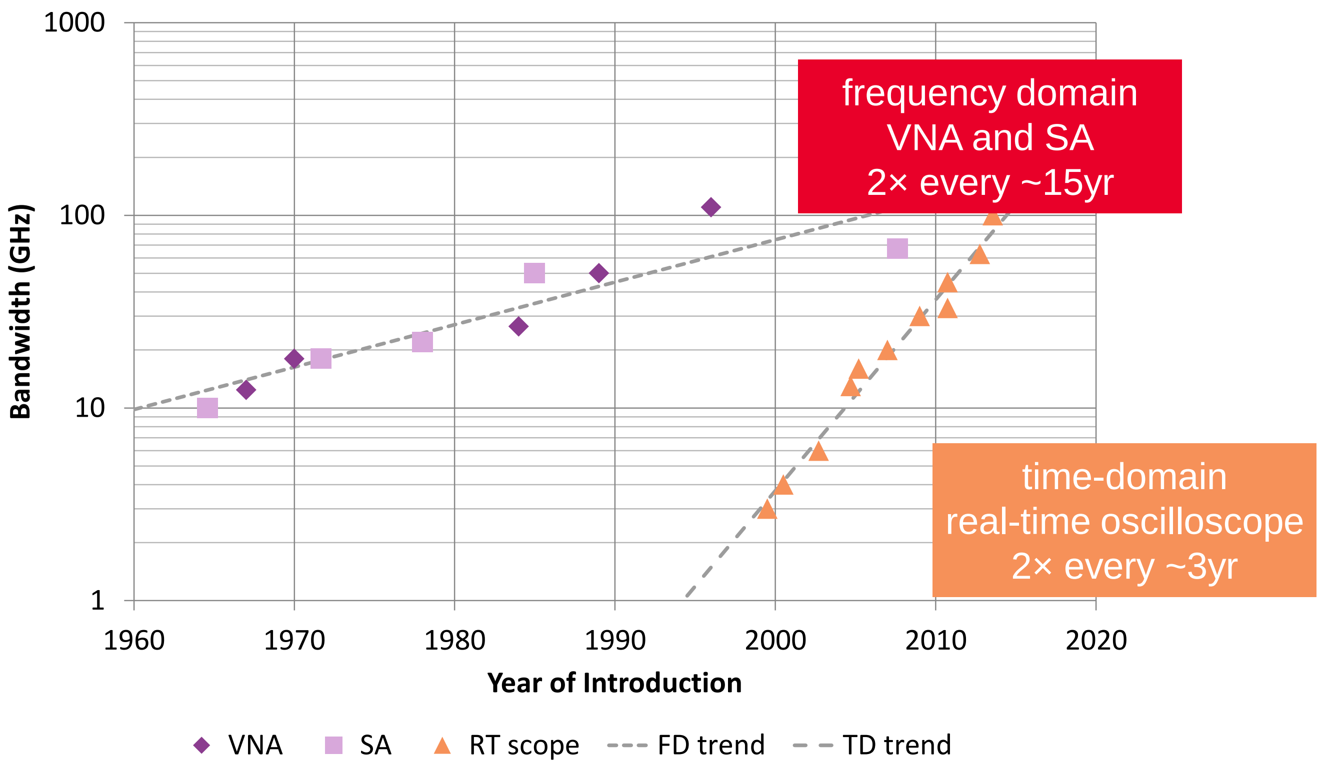
- Celluar via mmWave
- 1 Terabit Ethernet

Test & Measurement Equipment

THE NEXT TEN YEARS: HIGHER FREQUENCIES, WIDER MODULATION

T&M Frequency Race:

- Time domain vs Frequency domain
- Oscilloscopes vs Spectrum/Network



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