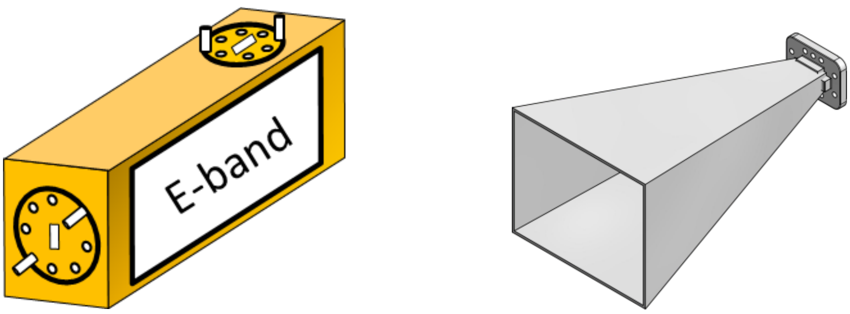
INTERLLIGENT
RF & Microwave Solutions

Training seminar programme:
Moving up to mm-waves



2 days (16 study hours) seminar

Includes theoretical background, animated presentations, and live demonstrations

RF training | Test equipment | Components & systems | Engineering solutions | RF ventures incubator

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Training seminar programme:

Moving up to mm-waves

Introduction:

Millimetre waves communications has been around for some time, but mm-wave technologies became a "hot topic" just recently, as these technologies are the key enablers for modern wireless applications such as 5G, WiGig, car radar, advanced imaging systems and more. While there are many system level benefits in using the mm-waves spectrum (such as wider available channel-bandwidths and smaller antennas), dealing with mm-waves engineering may introduce some unique challenges as well, which are nontrivial to "conventional" RF engineers. In this seminar, we shall discuss some of the key differentiators between mm-waves engineering and RF engineering, and introduce specific mm-waves system building blocks, design considerations and measurement set-ups.

Short form syllabus with time allocations:

Day #	Subject #	Covered content	Time allocated
1	1	***Introduction to mm-waves and some history***	0.5 hour
	2	***Coaxial transmission lines vs. waveguides***	2 hours
	3	***Millimetre waves components, accessories and system's building blocks***	2 hours
	4	***Millimetre waves spectrum analysis***	1.5 hours
	5	***Millimetre waves network analysis***	1.5 hours
2	6	**Up/ down converters and digitizers for broadband mm-waves signals**	4 hours
	7	***mm-wave transmitter's measurements***	1.5 hours
	8	***mm-wave receiver's measurements***	1.5 hour
	9	***Hands-on demonstrations***	1.5 hours
Total study duration			16 Hours

Target audience:

The target audience for this seminar consists of RF & microwave system engineers, wireless hardware experts and electronics engineers who plan to make a transition into mm-waves technology, and wish to understand its basic concepts and unique challenges.

Presenter:

The seminar will be presented by Mr. Oren Hagai, the founder of INTERLLIGENT RF and Microwave Solutions. Bio available online at: https://www.linkedin.com/in/4x1vi

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Detailed syllabus with suggested time allocations:

Subject	Covered content	Time allocated
Subject 1: ***Introduction and some history***	**Introduction to mm-waves technology:** ▪ Motivation for mm-waves communications ▪ Overview of modern mm-wave communications, radar and imaging applications ▪ Key differences between mm-waves engineering and "regular" RF engineering **Some mm-waves history:** ▪ Early days mm-waves communications and radar systems ▪ The Gunn diode and magnetron sources ▪ Tube amplifiers and early waveguides ▪ Early mm-waves synthesizers ("A-PLL")	0.5 Hours
Subject 2: ***Coaxial transmission lines vs. waveguides***	**Coaxial transmission lines in mm-waves:** ▪ "Mode free" transverse electromagnetic (TEM) waves propagation in a lossless and in lossy coaxial transmission lines. ▪ Conditions for the appearance of waveguide modes (TE01 and beyond) and significant losses in coaxial transmission lines: The influence of the electrical length between the conductors, the dielectric constant of the insulator, and the operating frequency on the electromagnetic wave's mode and the resulting losses. ▪ Motivation for air insulated central conductors in mm-waves coaxial transmission lines, connectors and adapters. **Waveguides:** ▪ Animation of electrical field modes within a rectangular waveguide ▪ The ridged, double ridged and the elliptical waveguides. ▪ Power handling capabilities in waveguides (vs. Coax) ▪ Calculation of cut-off frequencies according to the physical waveguide dimensions ▪ Standard WR and WG waveguide dimensions, cut-off frequencies and typical losses ▪ Standard waveguide to waveguide and waveguide to coax adapters	2 hours
Subject 3: ***mm-waves components, accessories and system's building blocks***	**mm-waves waveguide accessories and components:** ▪ The magic tee / mm-waves splitter ▪ The waveguide directional coupler ▪ Waveguide rotary vane attenuators (rotating resistive film) ▪ Waveguide rotary vane phase shifters **mm-waves active components:** ▪ Frequency multipliers and dividers (analogue pre-scalers) ▪ Fundamental and harmonic mm-wave mixers ▪ ***A few words about adapters, connectors, cables and standard waveguides***	2 hours
Subject 4: ***Mw-waves signal analysis***	**Millimetre waves spectrum analysis using a harmonic mixer** ▪ The harmonic mixer: basic mixer's architecture, spur chart and signal identification ▪ Preselected vs. broadband (folding) mm-waves mixers ▪ Phase noise performance degradation when using an external mm-wave mixer ▪ Maximal instantaneous BW limitations in harmonic mixing ▪ Mixer compression due to broadband noise, linearity verification procedures ▪ Methods for amplitude (CL) calibration for enhanced absolute power accuracy, applied to mm-wave external mixing **Millimetre waves noise figure measurements:** ▪ The Y-factor method, applied to mm-waves devices (non-frequency translating / frequency translating). ▪ Hidden error mechanisms when measuring mm-waves devices: Excessive (false reading) measured NF due to noise folding when using the "direct output noise density" NF measurement method with a harmonic mixer as a frequency extender for a signal analyser. ▪ Noise sources for mm-wave NF measurements	1.5 hours

(Detailed syllabus - continued…)

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Subject	Covered content	Time allocated
Subject 5: ***mm-wave network analysis***	**<u>Using mm-waves VNA frequency extenders:</u>** ▪ Extender architectures: T/R, Full S/parameters, power level control mechanisms ▪ Sweep span limitations when using frequency extenders ▪ System dynamic range limitations when using external frequency extenders. ▪ Standard waveguide calibration processes. **<u>Frequency offset measurements of mm-waves / IF converters:</u>** ▪ Scalar converter gain / loss measurements and set-up calibration ▪ Vector (scalar + group delay) converters measurements set-up calibration ▪ Frequency offset measurements of DUTs with embedded LO **<u>On wafer / PCB measurements:</u>** ▪ Key performance parameters of a mm-wave probe ▪ Reference plane offset phase / loss calibration ▪ Calibration substrates and TRL calibration	1.5 hours
Subject 6: ***Broadband up / down converters and digitizers***	**<u>Up/ down converters and digitizers for broadband mm-waves signals:</u>** ▪ Performance comparison of real-IF up / down converters vs. zero-IF up / down converters: Gain and phase flatness, image rejection and phase noise trade-offs. ▪ Residual EVM analysis of mm-waves up / down converters: Translating the converter's gain and phase flatness performance into residual EVM. ▪ Frequency plan considerations (f_{IF} vs f_{samp}) for the combination of wide instantaneous BW converters with broadband digitizers. ▪ Signal-to-quantization noise ratio and signal-to-aperture-jitter-voltage noise ratio in broadband digitizers	4 hours
Subject 7: ***mm-wave transmitter's measurements***	**<u>mm-waves transmitter's measurements:</u>** ▪ Power measurements using a mm-waves preselected true-RMS sensor ▪ Phase noise measurements using a mm-wave "smart-mixer" **<u>EVM measurements of digitally modulated signals at mm-waves:</u>** ▪ Methods for de-embedding the converter's residual EVM from a mm-wave's transmitter's EVM measurement: The comb-generator method and the gain / phase correction factors method. ▪ Standard test equipment set-ups that support broadband EVM measurements: The direct signal analysis approach, combination of down converter and a broadband oscilloscope, and custom set-ups.	1.5 hours
Subject 8: ***mm-wave receiver's measurements***	**<u>Generation of digitally modulated test signals at mm-waves, for mm-waves receivers measurements:</u>** ▪ Architectures of broadband receiver's test set-ups, using a broadband AWG and an up converter: Flatness and phase calibration, power calibration, LO leakage (DC offset) calibration (in case the converter is zero-IF). ▪	1.5 hours
Subject 9: **Hands-on demo**	**<u>Demonstrations as follows (depends on equipment availability):</u>** ▪ Signal analyser's frequency expansion, and the resulting spur responses ▪ Network analyser's frequency expansion, frequency offset measurements ▪ EVM measurements at mm-waves using a down-converter and an oscilloscope. ▪ Loading correction factors into Keysight's 89601B VSA software.	1.5 hours

We hope to see you at the seminar!

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