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Microstrip Low-Pass Filter Based Picosecond Pulse Expansion for PPM Demodulation

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Motivation

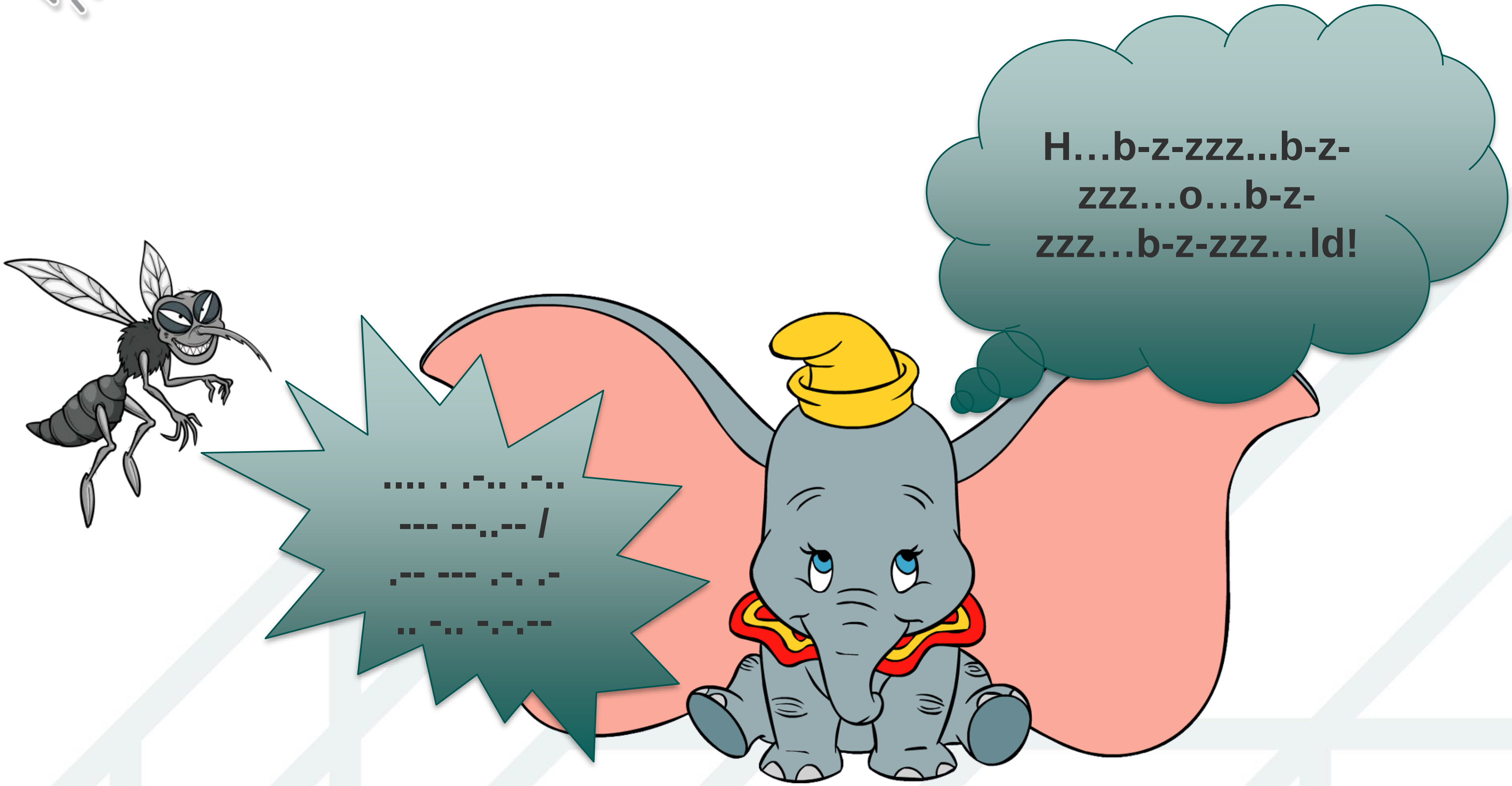
In diem scientia.

– possible phrase in Latin

- Pulse position modulation (PPM) is an energy efficient ultra-wideband (UWB) signaling technique.
- PPM pulses must be as short as possible for significant energy savings. We use 50 ps pulses (0 – 20 GHz).
- PPM signals can be detected and demodulated by event timers.
- Any timer is characterized by the minimal pulse duration at which it is triggered.

It is challenging to register pulses with duration below 100 ps!

Front-end solution should be designed and implemented!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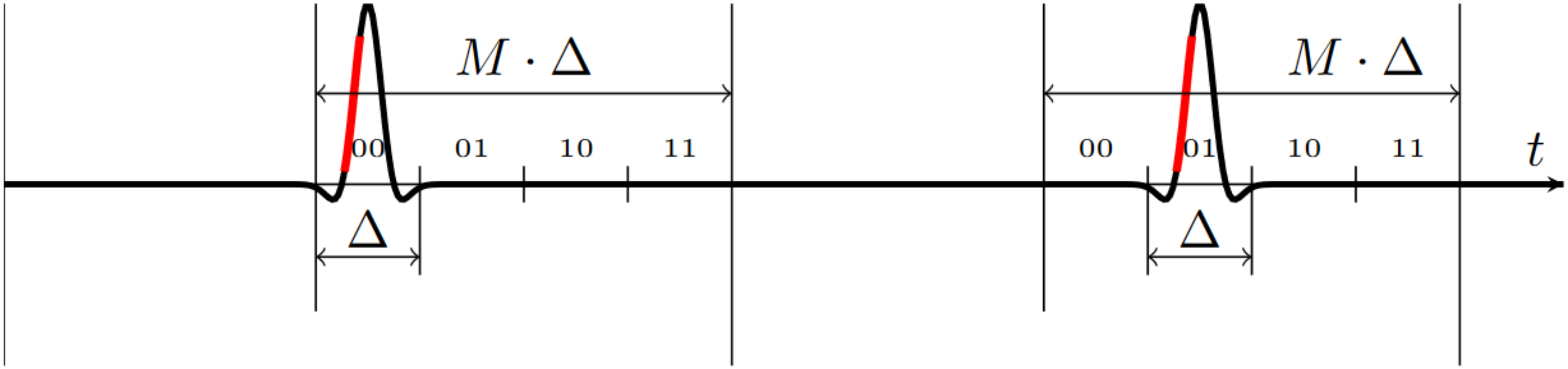
H…b-z-zzz…b-z-
zzz…o…b-z-
zzz…b-z-zzz…ld!

Outline

- ☐ Pulse position modulation (PPM)
- ☐ PPM detection by event timer
- ☐ Frontend
  - ☐ LPF selection
  - ☐ Commercial LPFs
  - ☐ LPF design and implementation
  - ☐ Experimental validation
- ☐ Conclusions

Pulse position modulation (PPM)



Structure of example PPM signal encoding **00** and **01**, where:

- Δ – duration of one position
- M – number of positions

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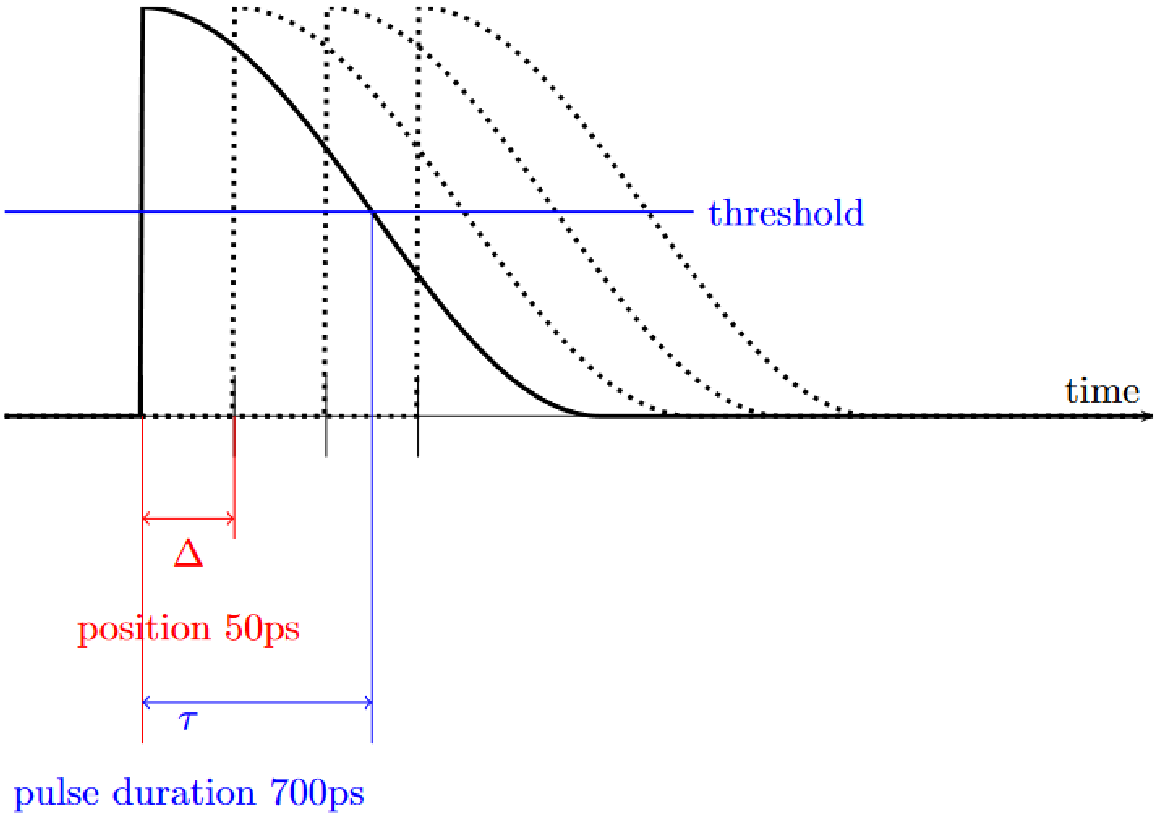
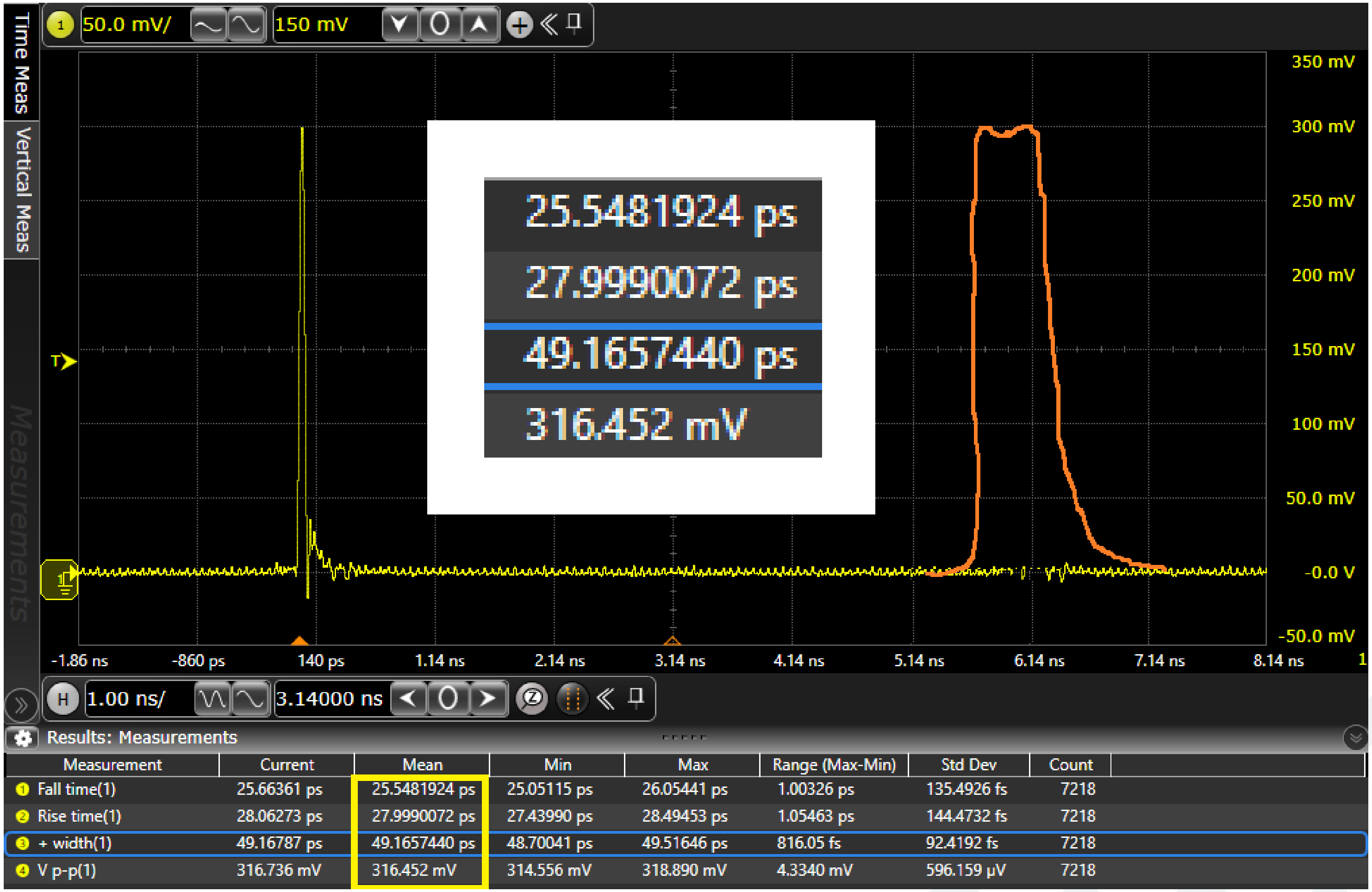
PPM detection by event timer – limits

http://eventechsite.com/en/products/event-timer-a033-et/



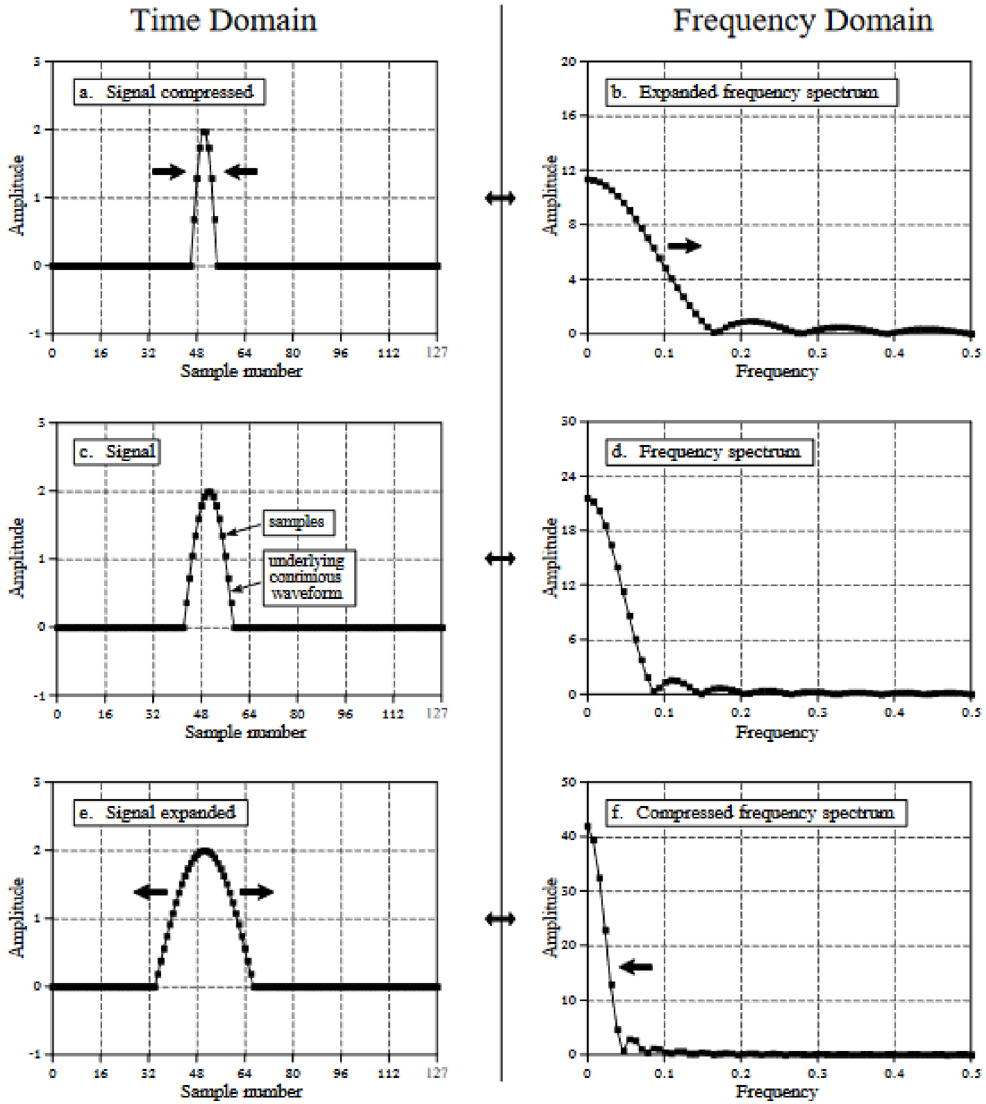
- Event timer, Eventech A033-ET, can detect events with a root mean square (RMS) accuracy of about 3 ps, but the pulse must be above the timer's pulse detection threshold for at least 700 ps.
- Therefore, in most cases, it is necessary to perform pulse shaping, expansion, and automatic gain control before detection by the event timer.

PPM detection by event timer – the task



- Pulse generation – AWG Keysight M8195
- Pulse time function measurements – digital storage oscilloscope (DSO), Keysight DSAZ334A, 80 GSa/s, 33 GHz)

PPM detection by event timer – principle of solution



Compression of the signal in frequency domain results in an expansion in time domain, and vice versa.

[Image from book The Scientist and Engineer's Guide to Digital Signal Processing by Steven W. Smith, Ph.D.]

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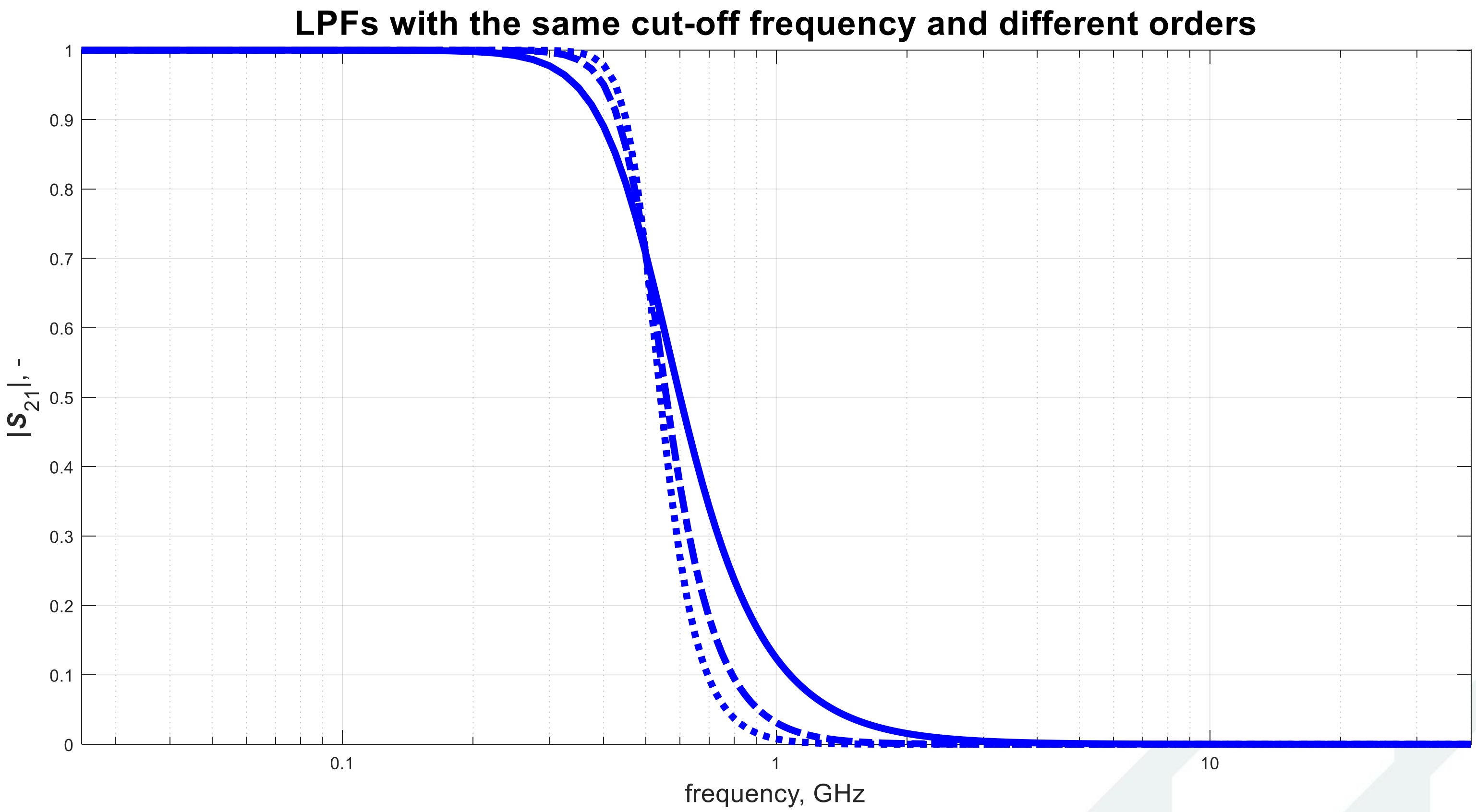
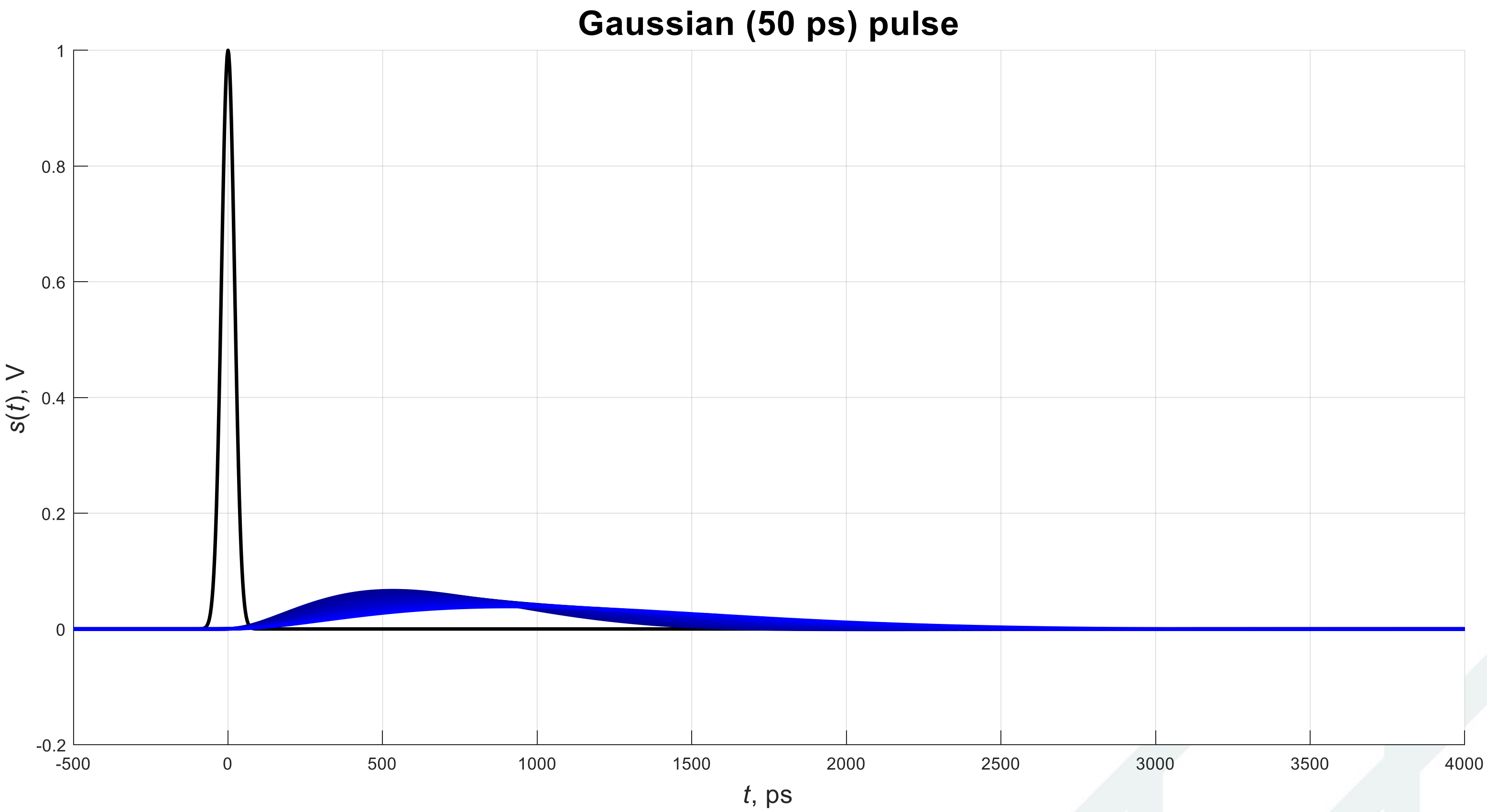
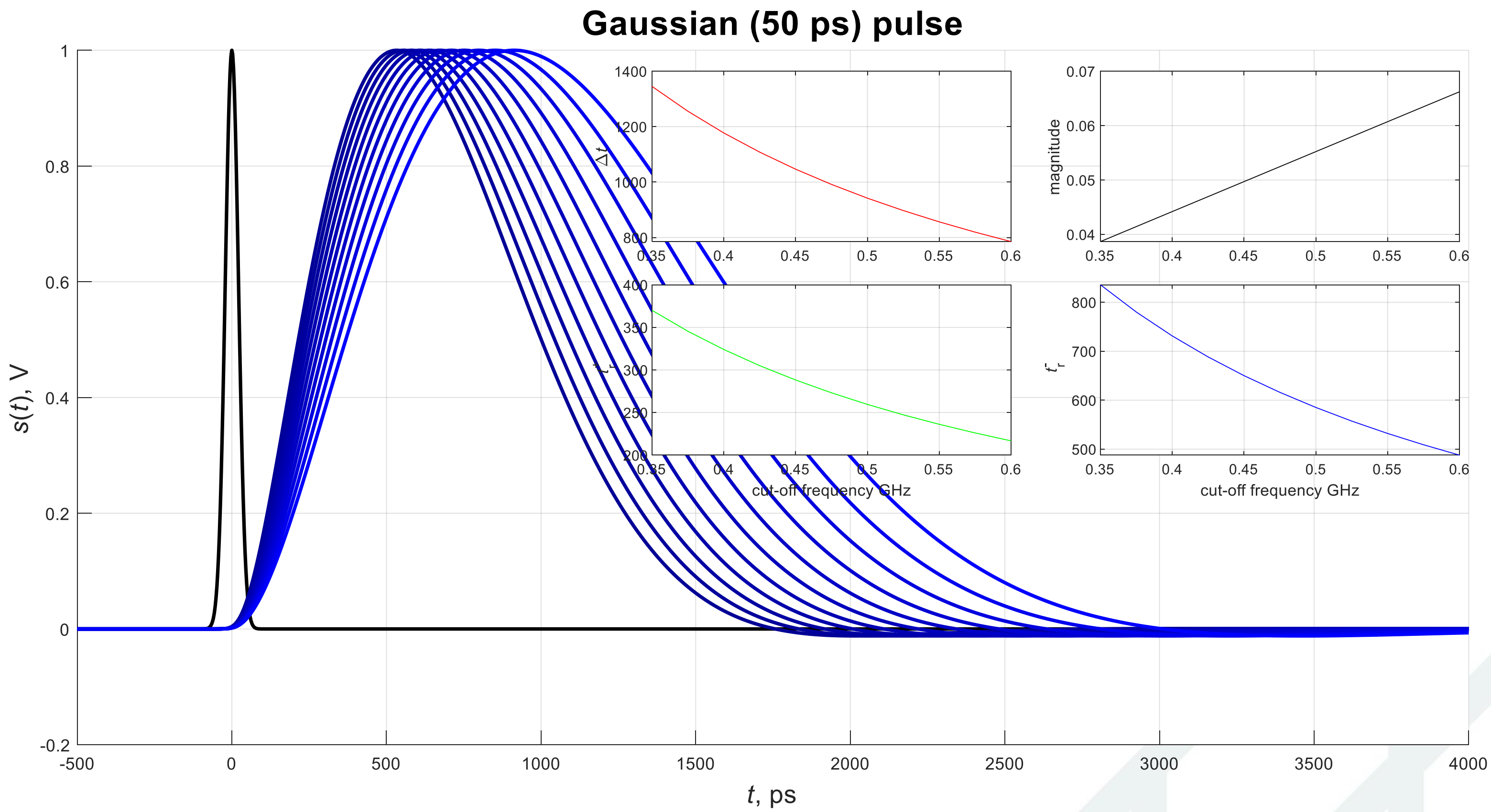
LPF selection – typical frequency characteristics



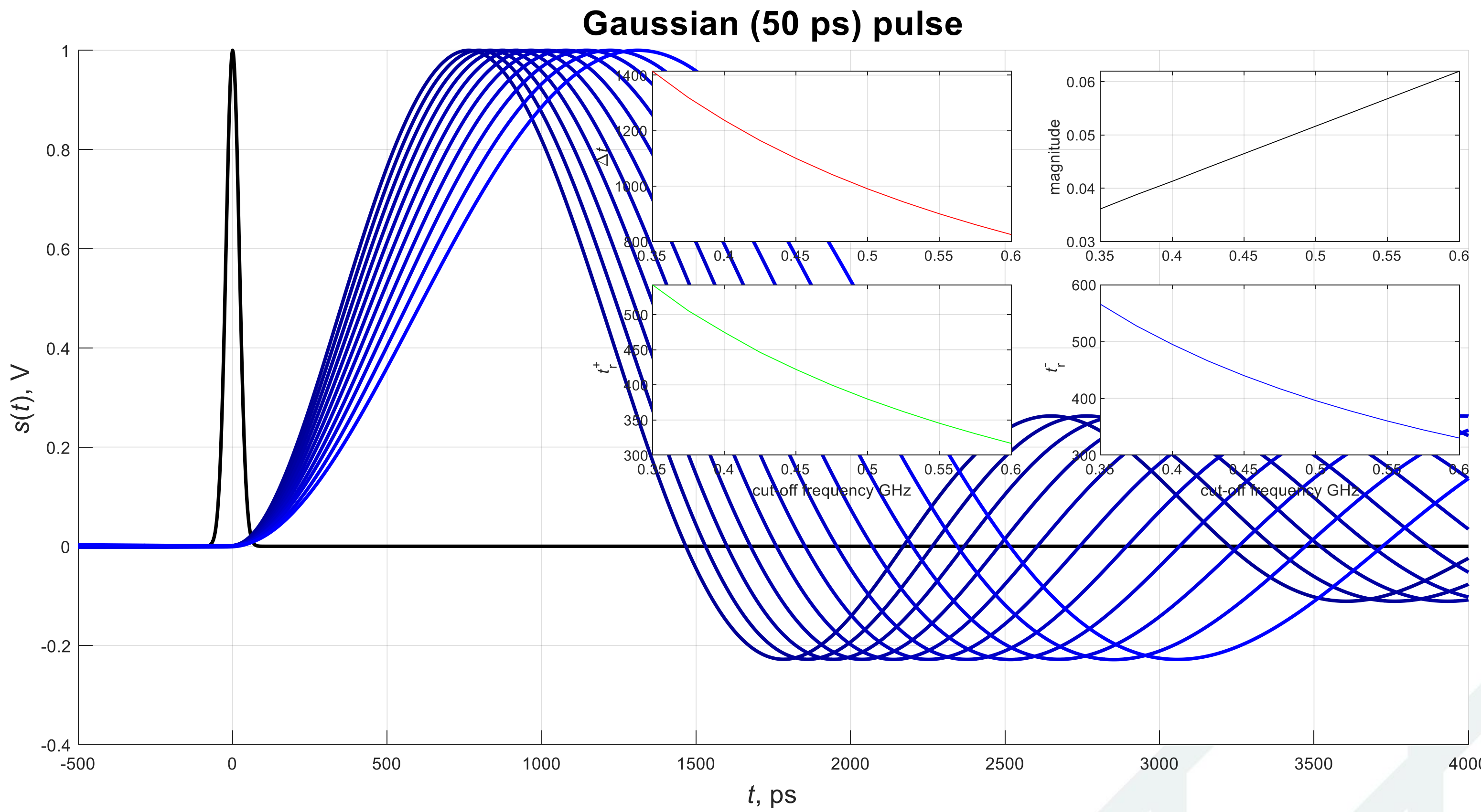
LPF selection – influence on pulse shape



LPF selection – influence on pulse shape (normalized)



LPF selection – influence on pulse shape (normalized)



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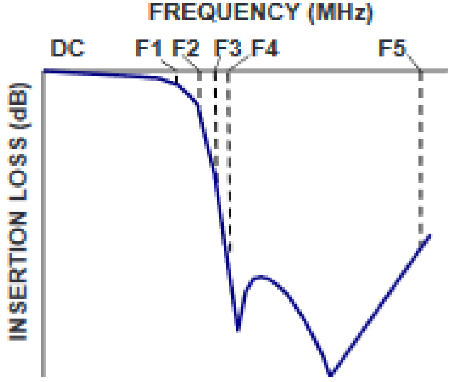
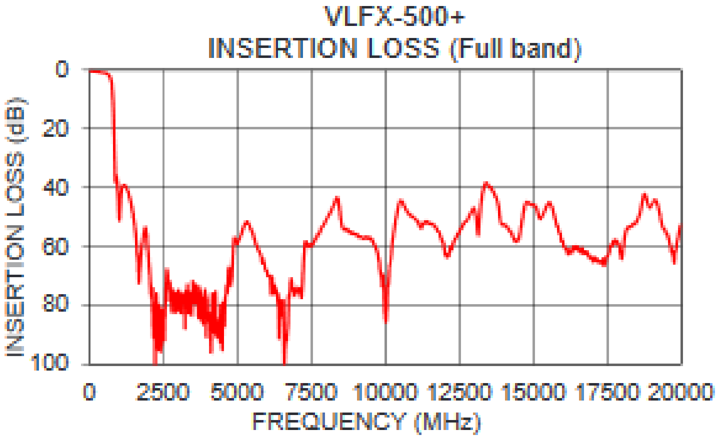
Commercial LPFs

Electrical Specifications[1] at 25°C

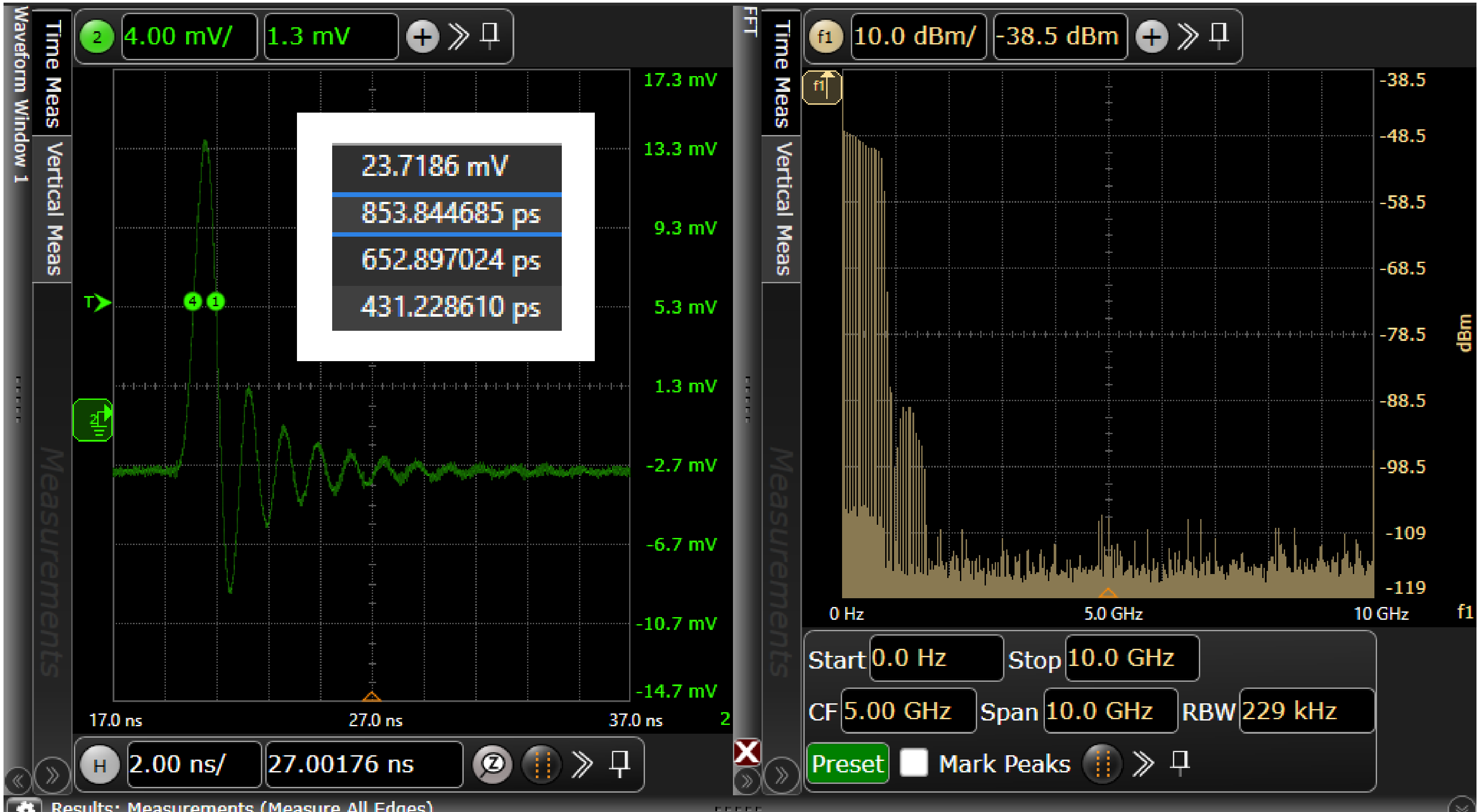
Parameter		F#	Frequency (MHz)	Min.	Typ.	Max.	Unit
Pass Band	Insertion Loss	DC-F1	DC-500	—	1.1	1.6	dB
	Freq. Cut-Off	F2	750	—	3.0	—	dB
	VSWR	DC-F1	DC-500	—	1.15	—	:1
Stop Band	Insertion Loss	F3	900	20	33	—	dB
		F4-F5	1100-20000	—	40	—	dB
	VSWR	F3-F5	900-20000	—	10	—	:1

Typical Frequency Response





Commercial LPFs – VLFX-500+, LTCC LPF, DC - 500 MHz



Measurement	Current	Mean	Min	Max	Range (Max-Min)	Std Dev	Count
V p-p(2)	23.5233 mV	23.7186 mV	23.3673 mV	27.7326 mV	4.36532 mV	497.856 µV	140
+ width(2)	852.81977 ps	853.844685 ps	721.19625 ps	880.75677 ps	159.56052 ps	12.9723614 p	45616
Rise time(2)	629.64521 ps	652.897024 ps	568.45969 ps	874.00301 ps	305.54332 ps	16.2879140 p	45616
Fall time(2)	424.09028 ps	431.228610 ps	394.85053 ps	703.54612 ps	308.69558 ps	13.9582912 p	45616

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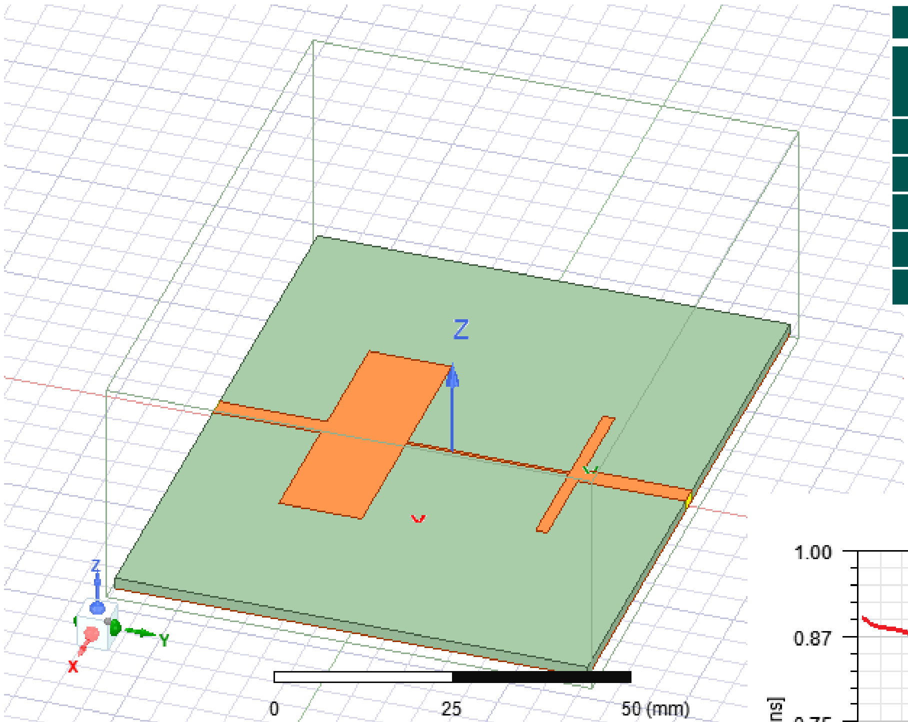
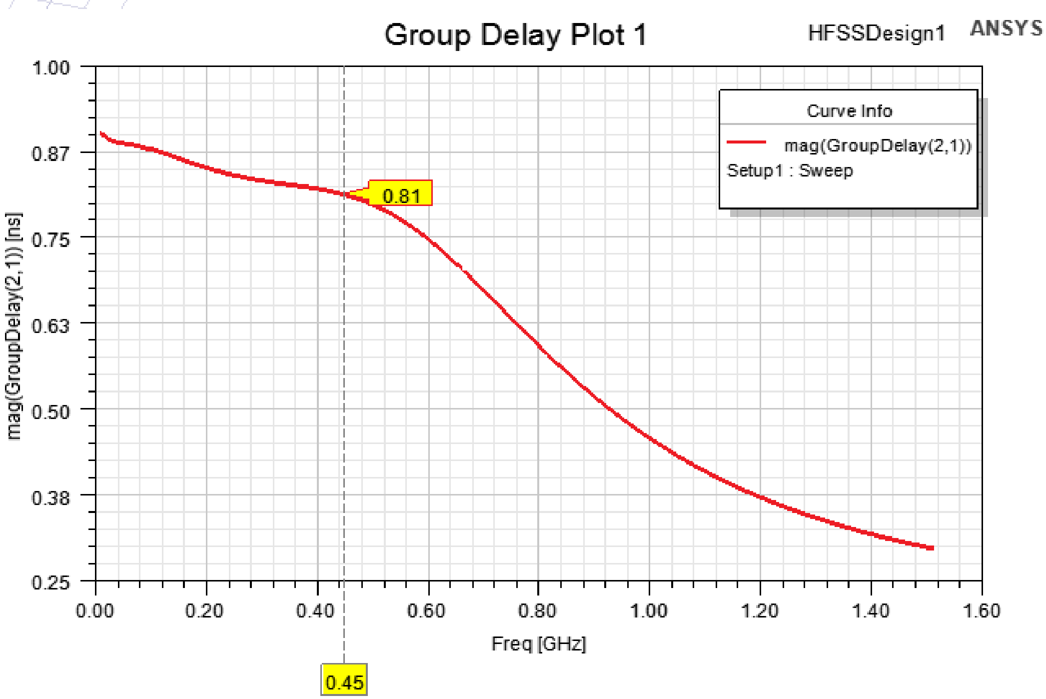
LPF design and implementation – microstrip – HFSS

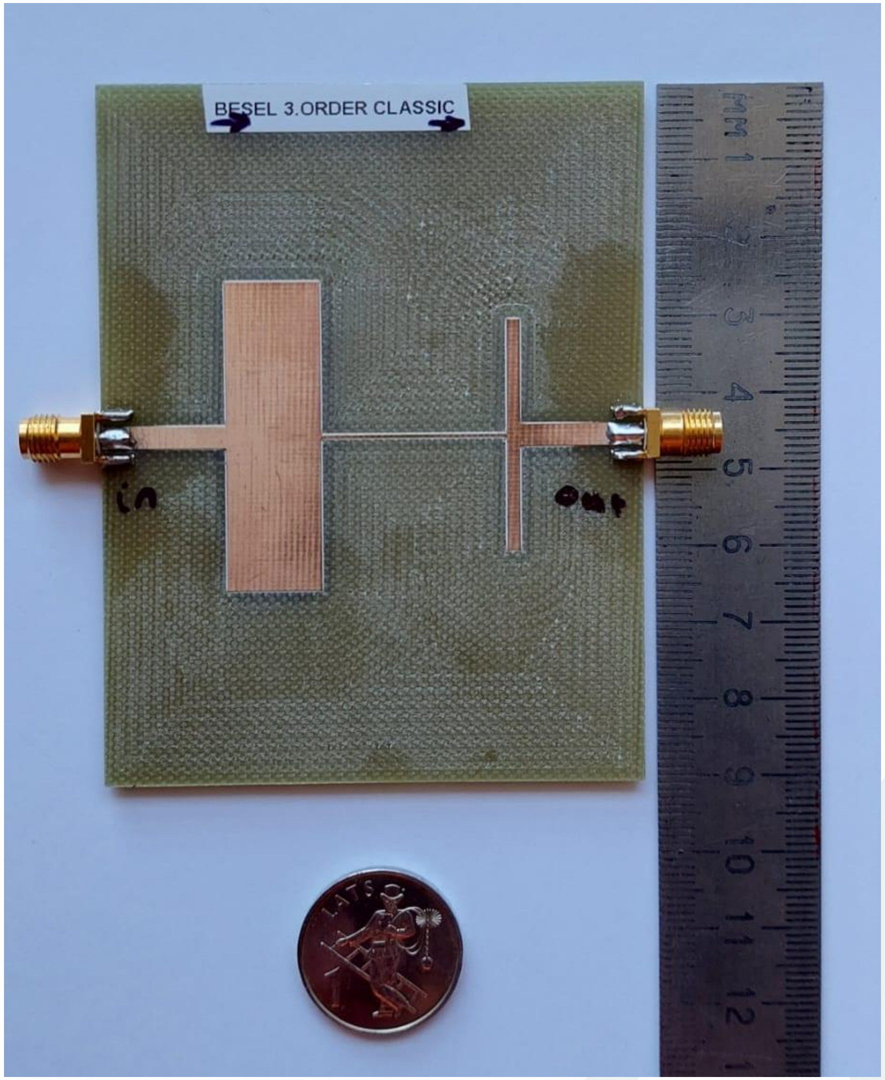


Values of filter elements		
Impedance [Ω]	Strip width [mm]	Strip length [mm]
50.100	2.9	15.95
6.344	40.0	12.27
109.130	0.5	24.10
8.240	30	1.74
50.100	2.9	15.95

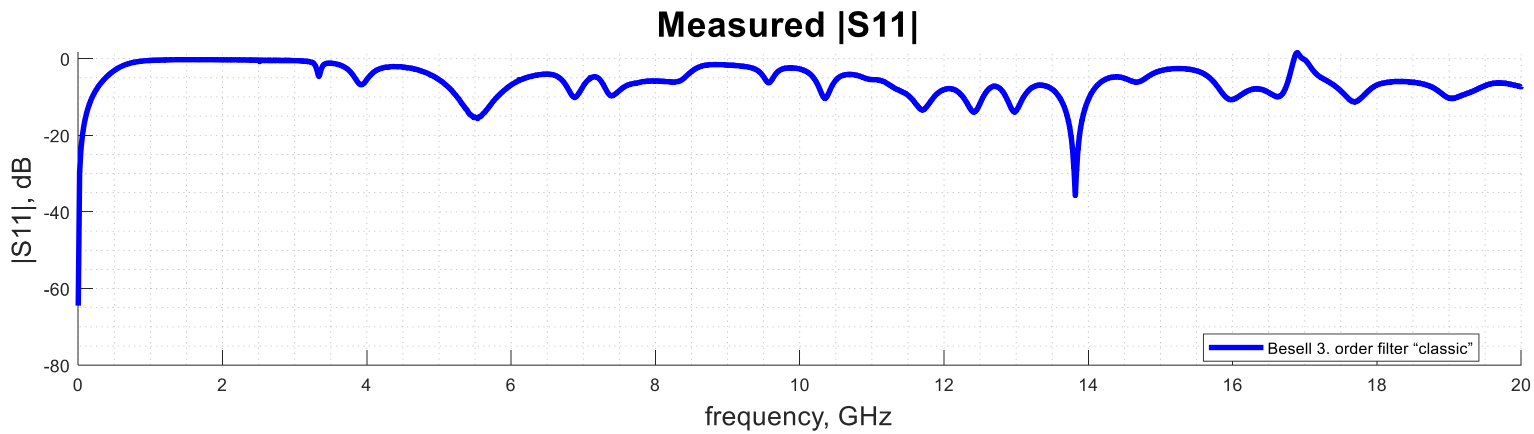
LPF (lumped-parameters circuit equivalent)	
Elements	At Rin = Rout = 50 Ω and $f_{cut\text{-}off}$ = 500 MHz)
C1	14.03 pF
L2	15.45 nH
C3	2.15 pF

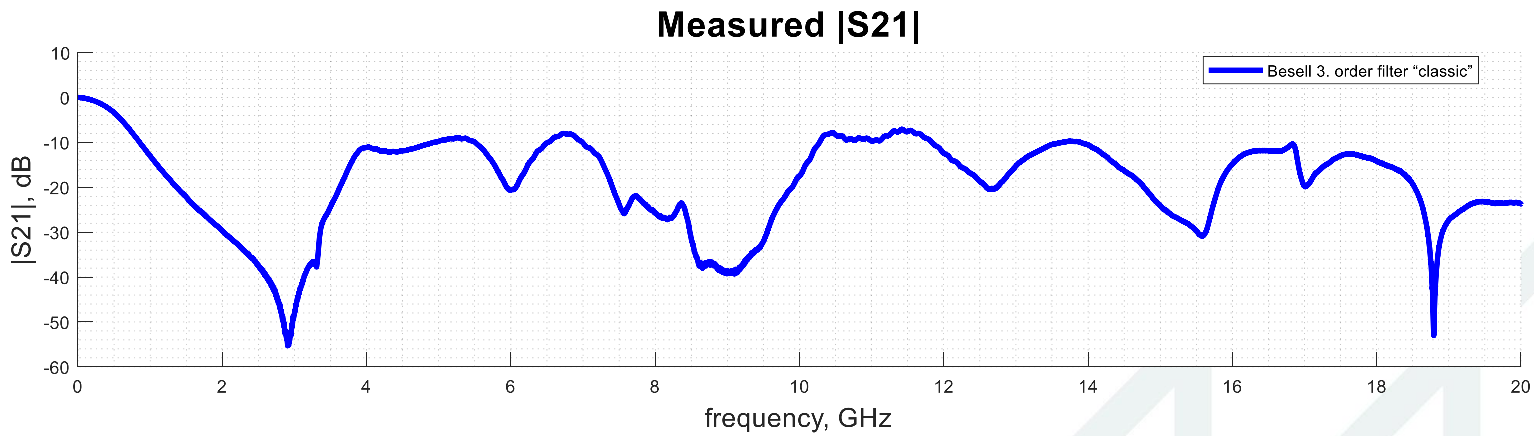


LPF design and implementation – microstrip – real



LPF design and implementation – microstrip – measured spectral characteristics





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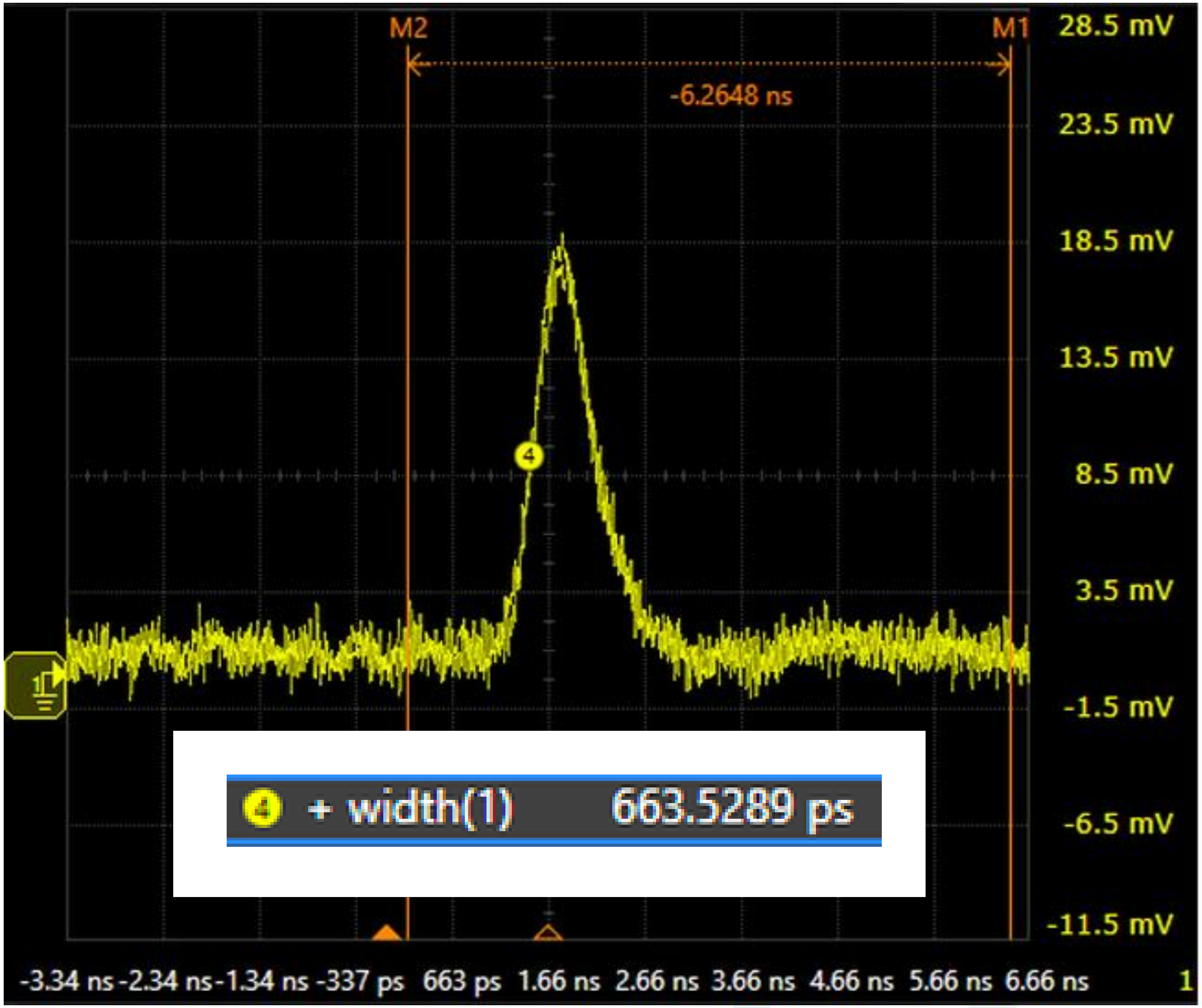
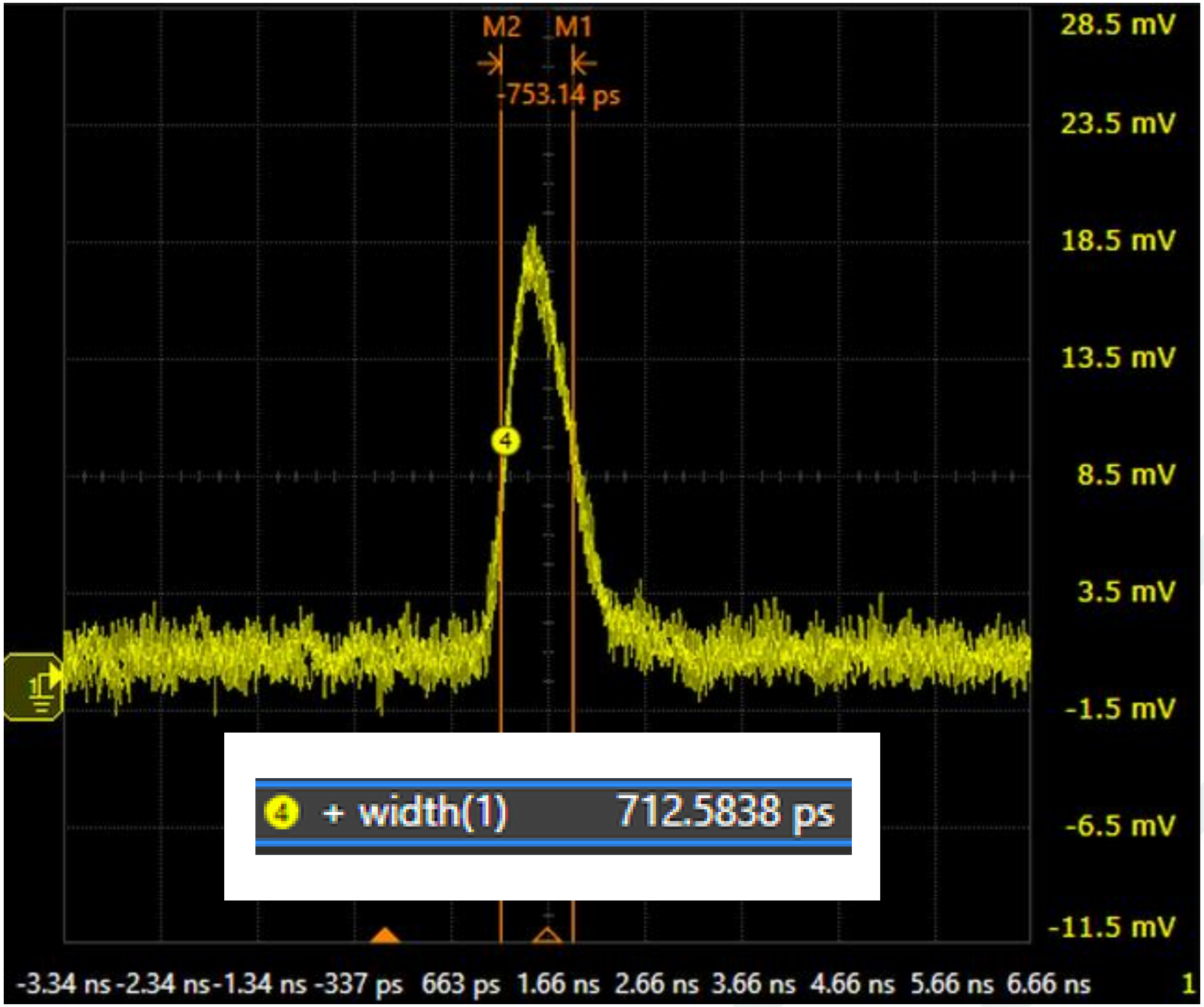
Experimental validation – microstrip – alone

Experimental validation – microstrip – in cascade with VLFX 1300+



Experimental validation – microstrip – in cascade with VLFX 2500+



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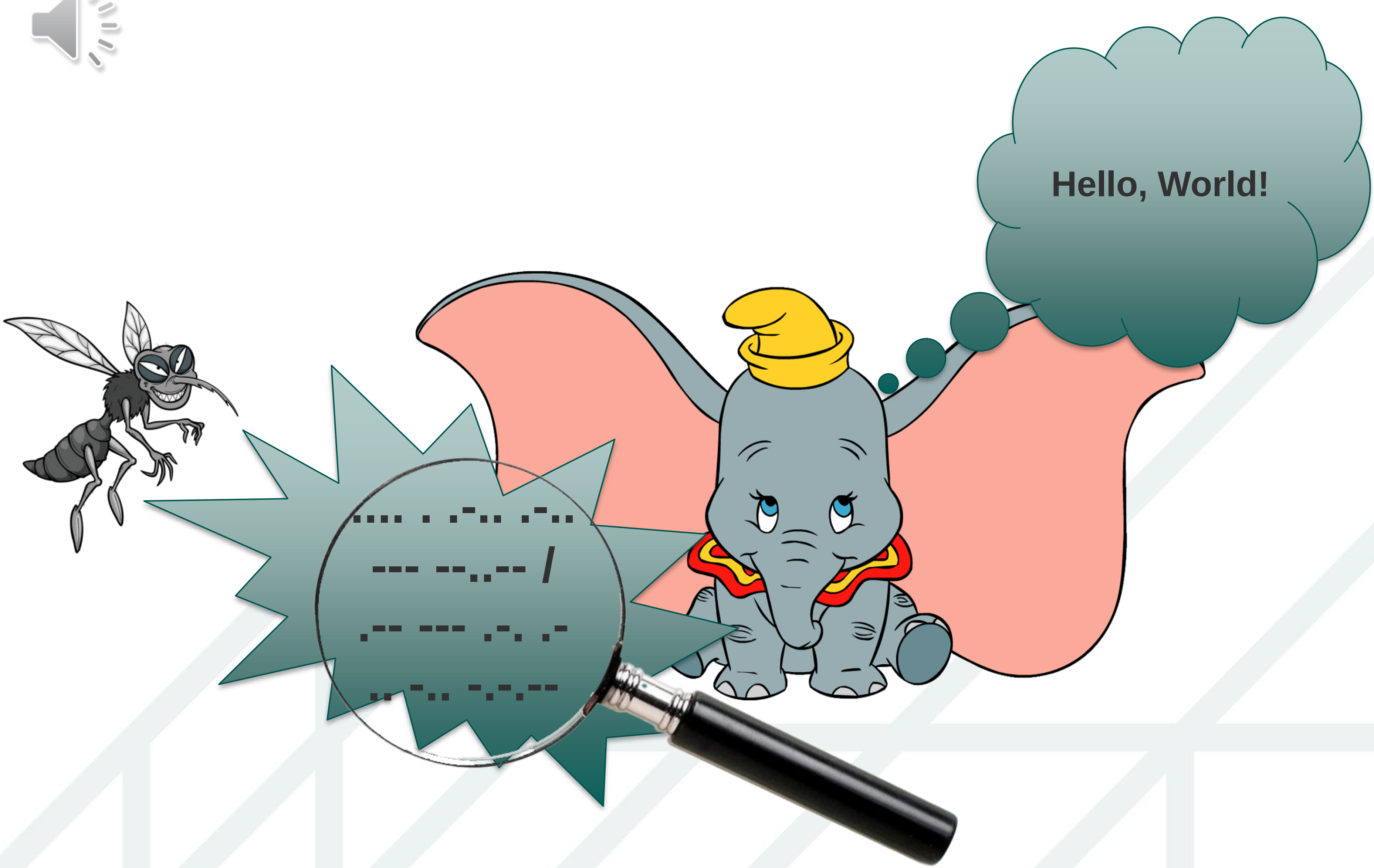
Conclusions

- For a 50 ps pulse expansion to 700 ps, low-pass filters (LPFs) of Bessel type, third order, with a cut-off frequency of 500 MHz implemented using microstrip technique could be employed.

- To achieve a smooth and undistorted expanded pulse shape, a cascade connection of filters with two different frequency characteristics can be utilized. This approach would provide a smooth cut-off at the low-frequency range and sufficient suppression at the high-frequency range.

- Given methodology allows to use high precision event-timer which requires relatively long pulses.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Hello, World!

Thank You for attention!