DBBT
Digital Broadcasting & Broadband Technologies

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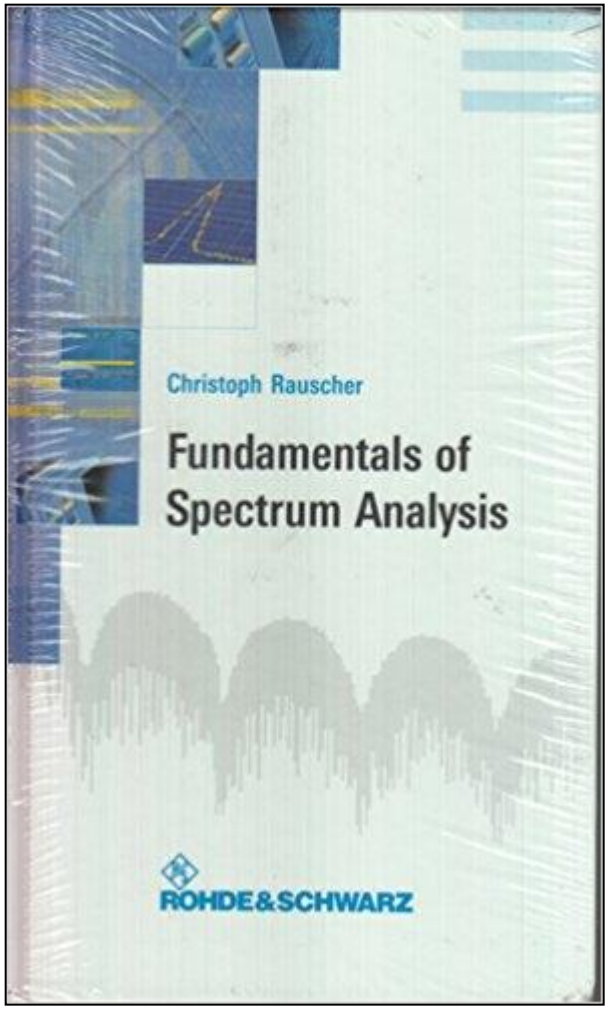
Telekomunikaciona merenja
TM P05 2018

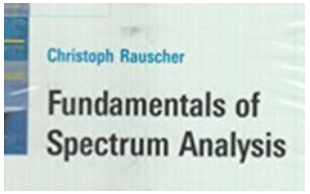
Profesor dr Miroslav Lutovac

"This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein"

Osnove analize spektra

Rauscher C.,
Fundamentals of Spectrum Analysis,
Rohde & Schwarz, 2006

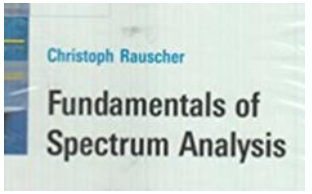




Opseg primene

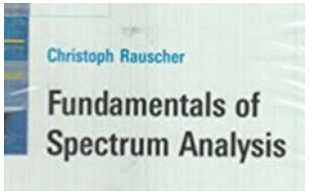
Najviša učestanost merenja spektra

- do ≈ 1 MHz, elektronika, akustika, mehanički sistemi
- do ≈ 3 GHz , RF opseg, bežične i mobilne telekomunikacije, širokopojasni audio i TV sistemi
- do ≈ 40 GHz, mikrotalasna tehnika
- iznad 40 GHz, milimetarski talasi, digitalni radio



Fourijeova analiza

- **Vremenski** i **frekvencijski** domen su **povezani** sa **Fourijeovom transformacijom**
- Za tačno određivanje spektra potrebno je poznavanje signala u **beskonačnom vremenskom domenu**
- **Vrednost amplitude** mora biti poznata u svakom vremenskom trenutku (**kontinualno**)
- **Spektar** će biti **kontinualan**, takođe, što znači da je frekvencijska rezolucija neograničena
- **Tačna izračunavanja nisu moguća u praksi**
- spektar može **da se odredi sa dovoljnom tačnošću** pod određenim pretpostavkama



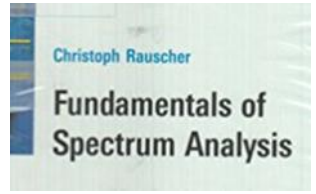
Diskretna Fourijeova analiza?

- Signal se odmerava u jednakim vremenskim intervalima (uzorkuje, odabira) sa analogno digitalnim konvertorom koji vrši kvantizaciju amplitude
- Od kontinualnog signala se dobija vremenski diskretan sa konačnim brojem vrednosti amplitude
- Da se izbegnu efekti prelivanja spektra, i efekti pojave odraza u frekvencijskom domenu, spektar signala mora da bude ograničen
- Šanonov zakon odabiranja (Shannon's law of sampling)

$$f_S \geq 2 \cdot B_{in} \quad \text{and} \quad f_S = \frac{1}{T_S}$$

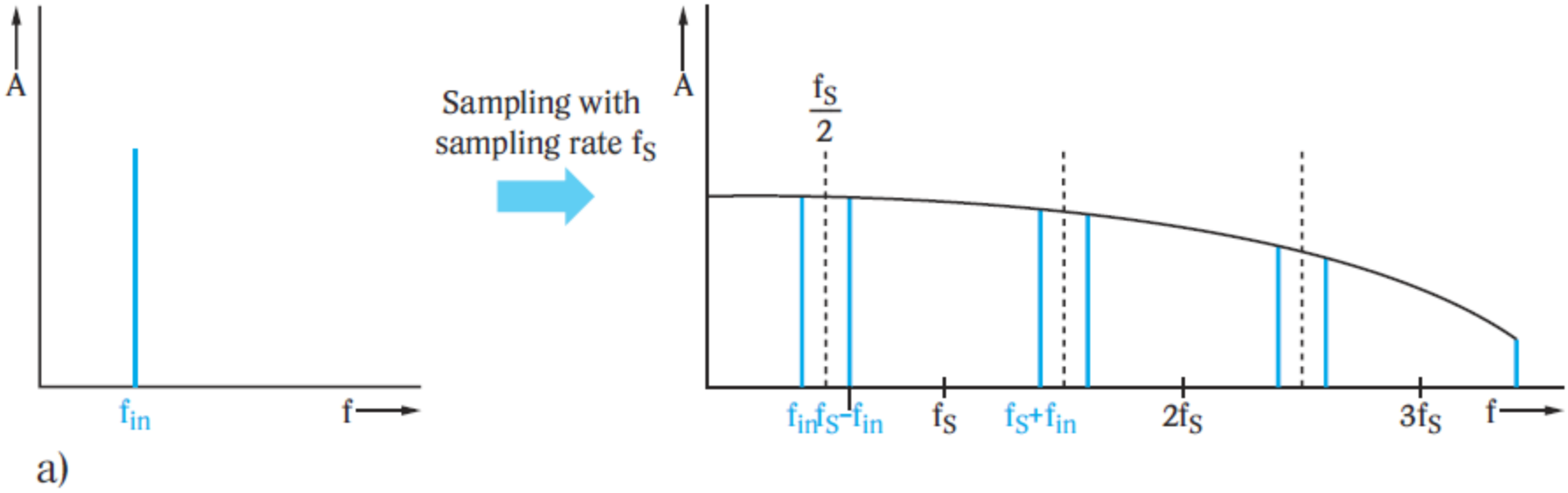
f_S	=	sampling rate, in Hz
B_{in}	=	signal bandwidth, in Hz
T_S	=	sampling period, in s

Diskretizacija signala u vremenu

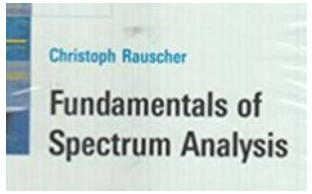


- $f_{in,\,max} < f_s/2$

✓ Sinusoidalan signal

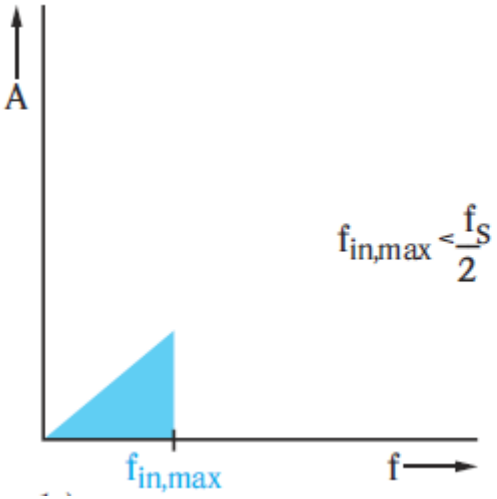


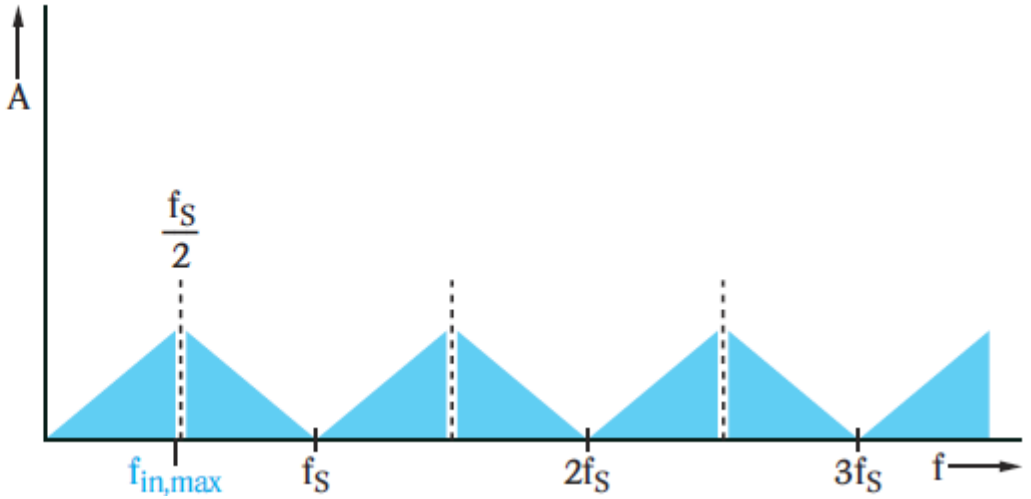
Diskretizacija signala u vremenu



- $f_{in,\,max} < f_s/2$

✓ Signal sa trougaonim spektrom





Diskretizacija signala u vremenu

- $f_{in,\,max} > f_s/2$

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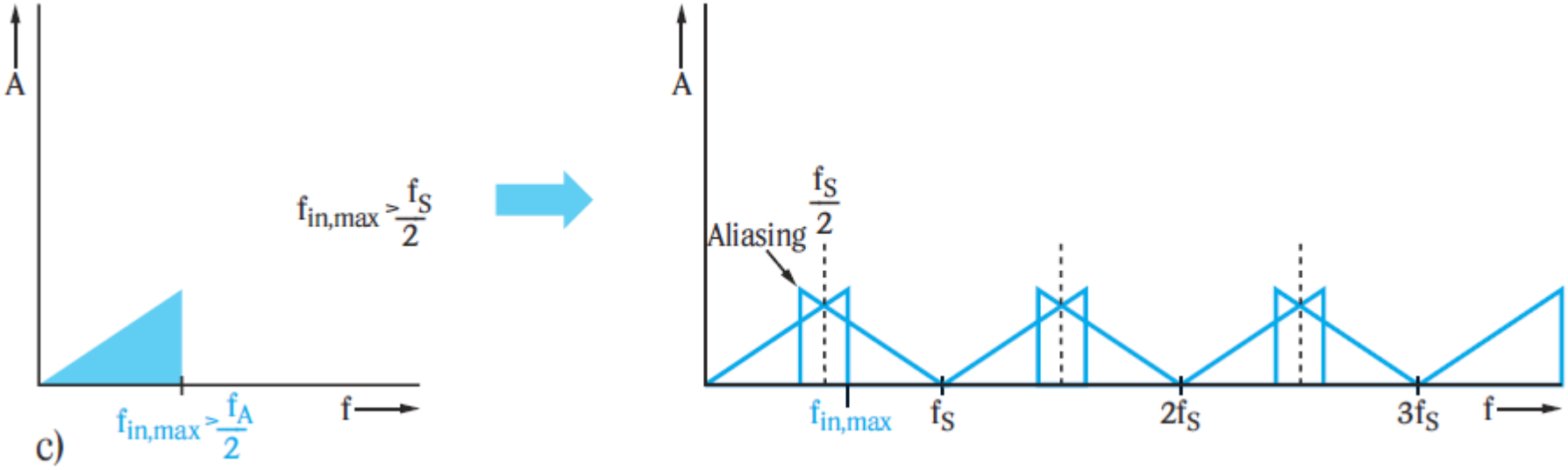
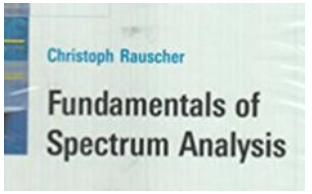


Dvosmislenost u blizini polovine učestanosti odabiranja, $f_s/2$



Diskretna Fourijeova analiza

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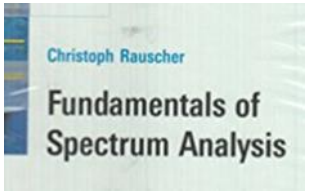
f_S	=	sampling rate, in Hz
B_{in}	=	signal bandwidth, in Hz
T_S	=	sampling period, in s

$$\underline{X}(k) = \sum_{n=0}^{N-1} \underline{x}(nT_S) \cdot e^{-j2\pi kn/N}$$

k	=	index of discrete frequency bins, where k = 0, 1, 2, …
n	=	index of samples
$\underline{x}(nT_S)$	=	samples at the point $n \cdot T_S$, where n = 0, 1, 2 …
N	=	length of DFT, i.e. total number of samples used for calculation of Fourier transform



Diskretna Fourijeova analiza

$$f_S \geq 2 \cdot B_{in} \quad \text{and} \quad f_S = \frac{1}{T_S}$$

f_S	=	sampling rate, in Hz
B_{in}	=	signal bandwidth, in Hz
T_S	=	sampling period, in s

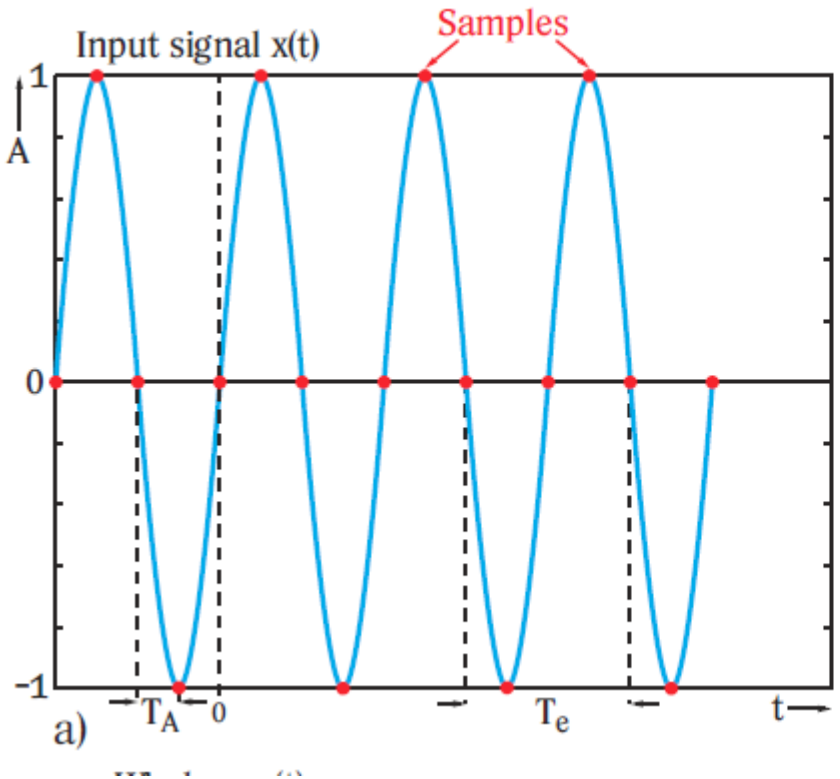
$$f(k) = k \cdot \frac{f_S}{N} = k \cdot \frac{1}{N \cdot T_S}$$

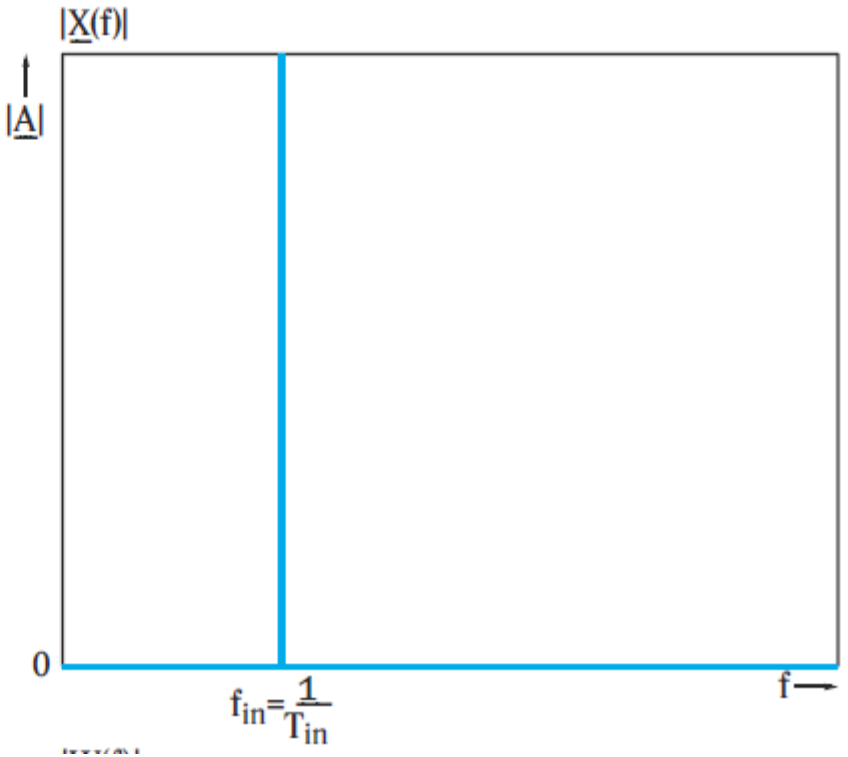
f (k)	=	discrete frequency bin, in Hz
k	=	index of discrete frequency bins, with k = 0, 1, 2 …
f_A	=	sampling frequency, in Hz
N	=	length of DFT

Signal u vremenskom i frekv. domenu

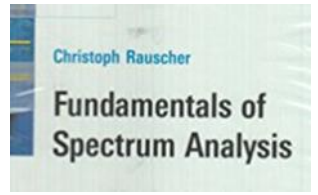
Christoph Rauscher
Fundamentals of Spectrum Analysis

✓ Sinusoidalan signal beskonačnog trajanja

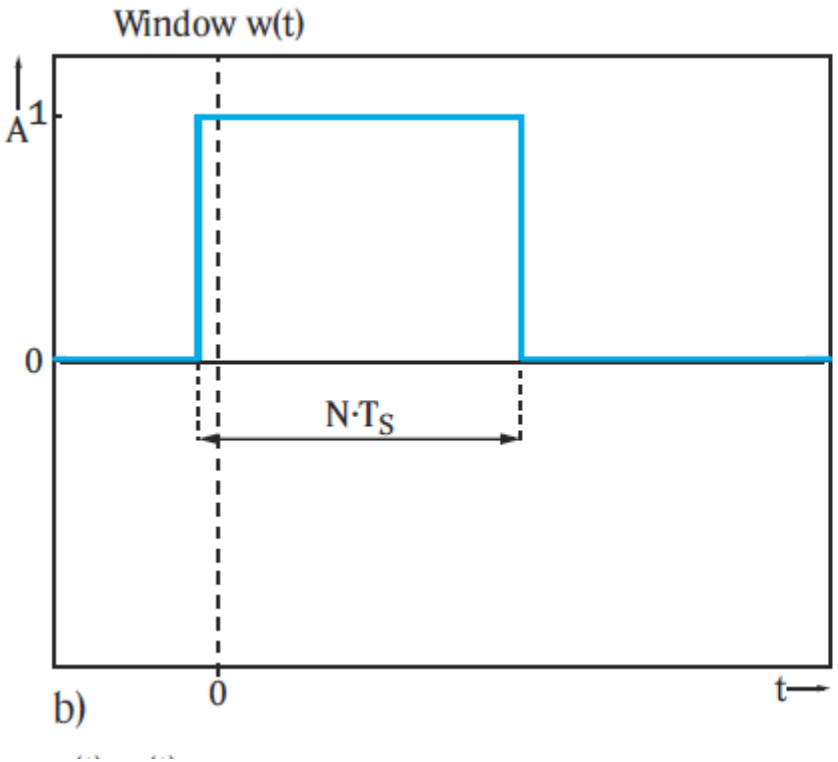


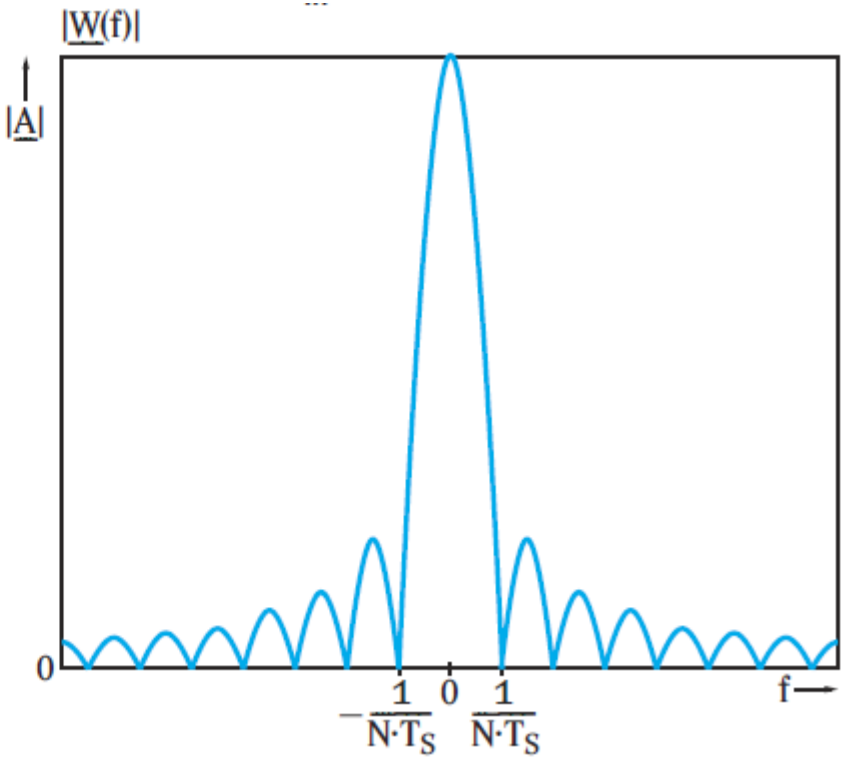


Signal u vremenskom i frekv. domenu

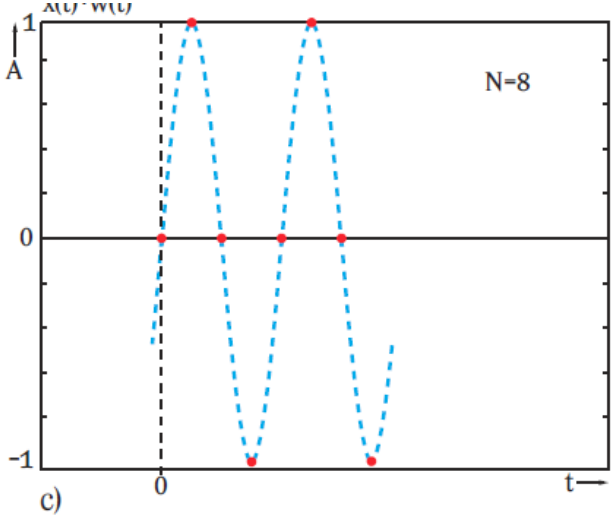


✓ Pravougaoni signal

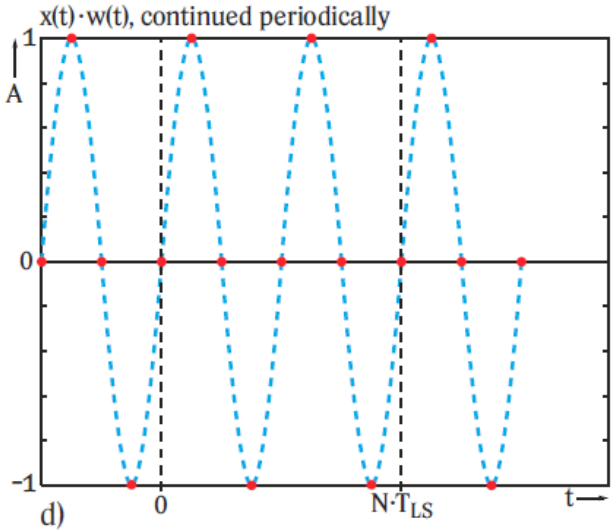


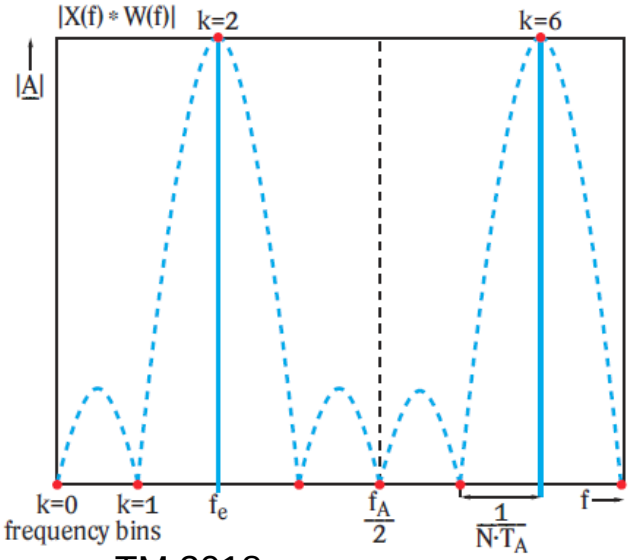


Signal u vremenskom i frekv. domenu



- ✓ Sinusoidalan signal ograničenog trajanja





Signal u vremenskom i frekv. domenu

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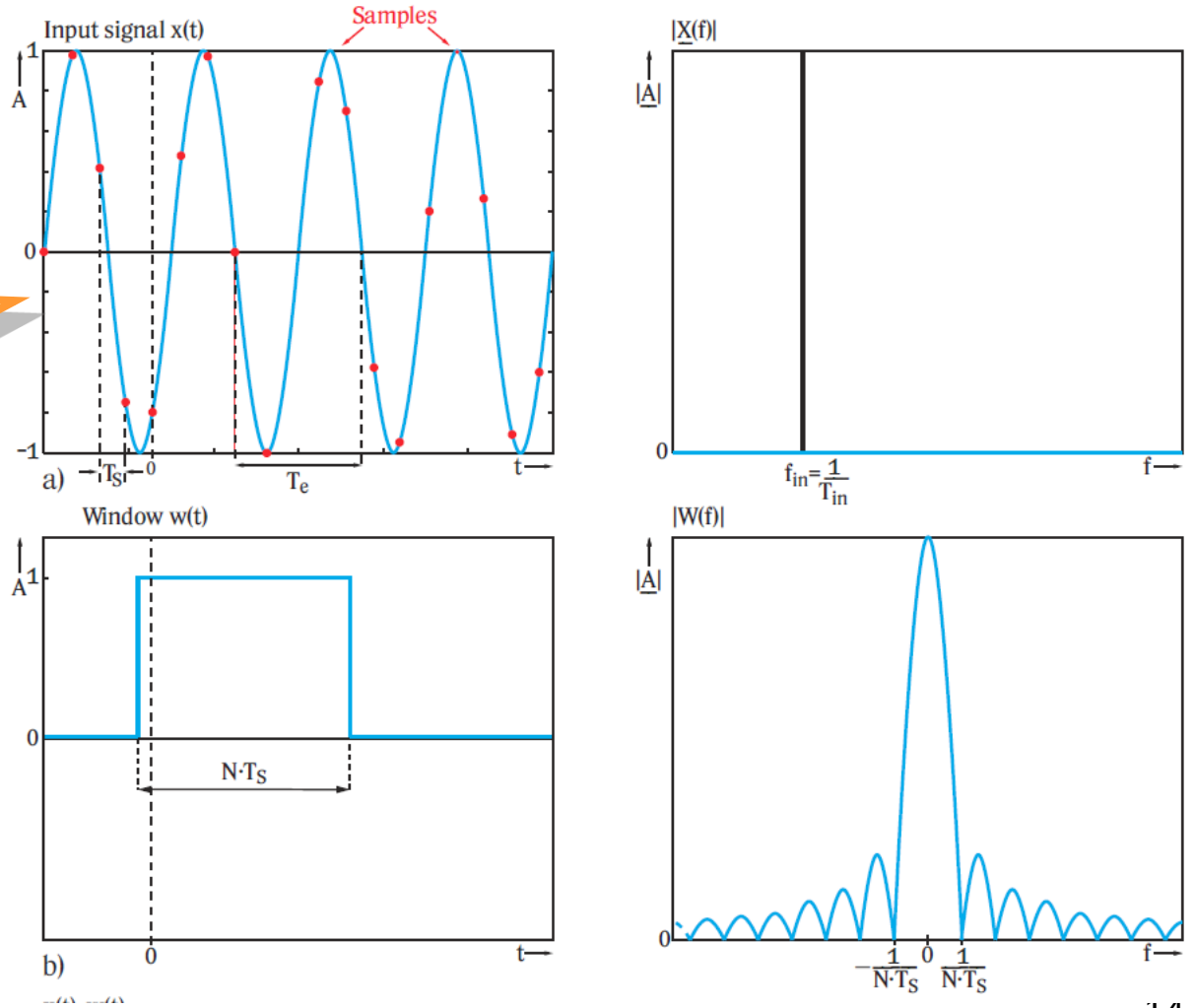
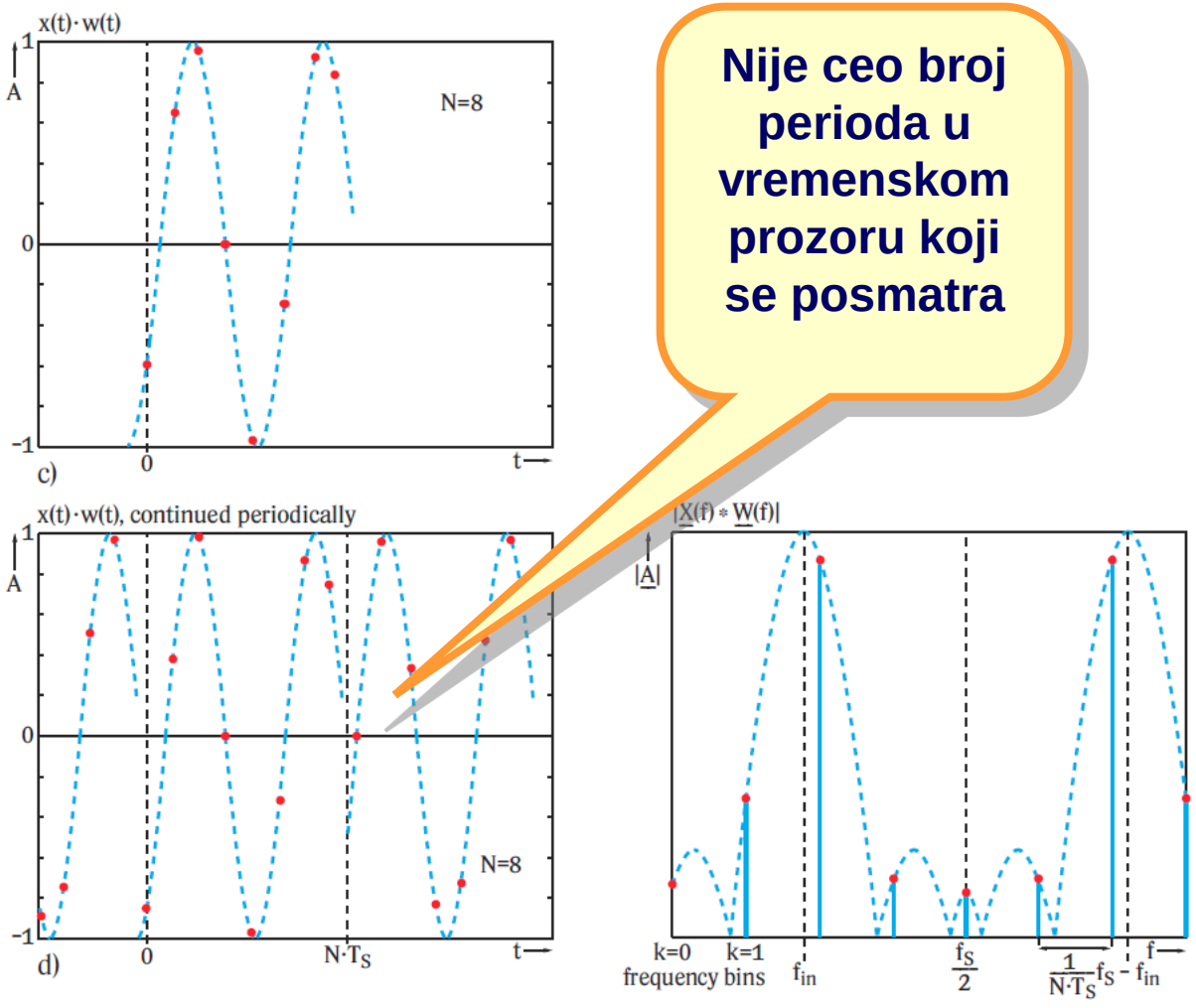
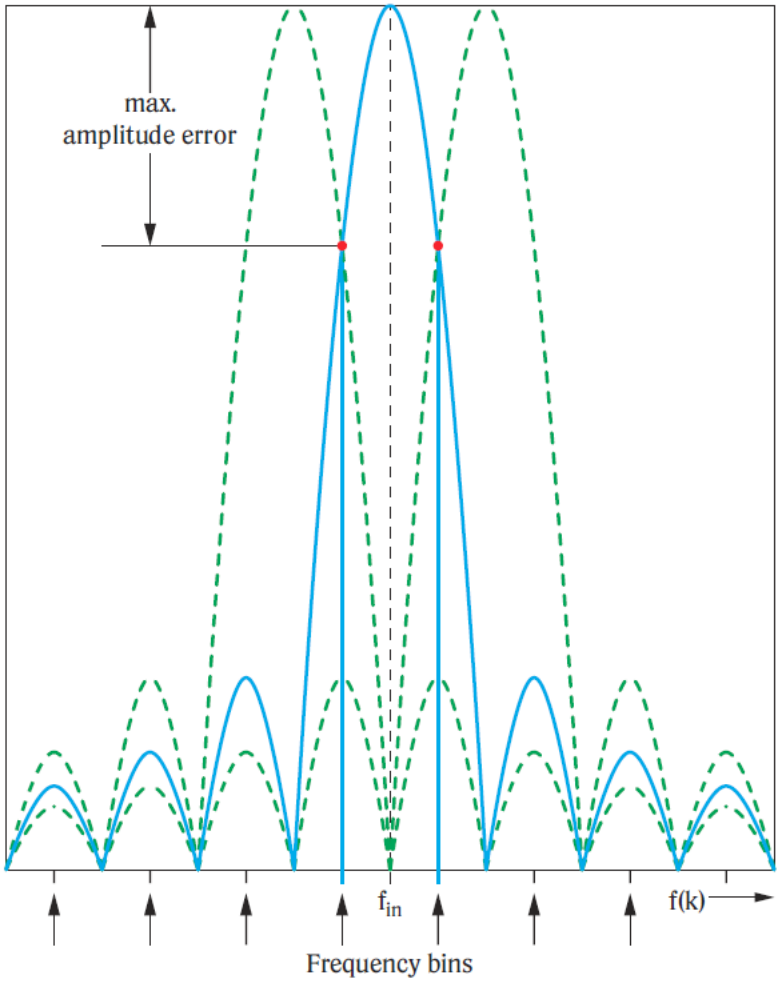
Ceo broj perioda u vremenskom prozoru koji se posmatra



Signal u vremenskom i frekv. domenu



Signal u vremenskom i frekv. domenu



Greška u amplitudi koja je nastala usled ograničenog vremenskog prozora koji se posmatra u funkciji učestanosti

Signal u frekv. domenu i vremenski prozor

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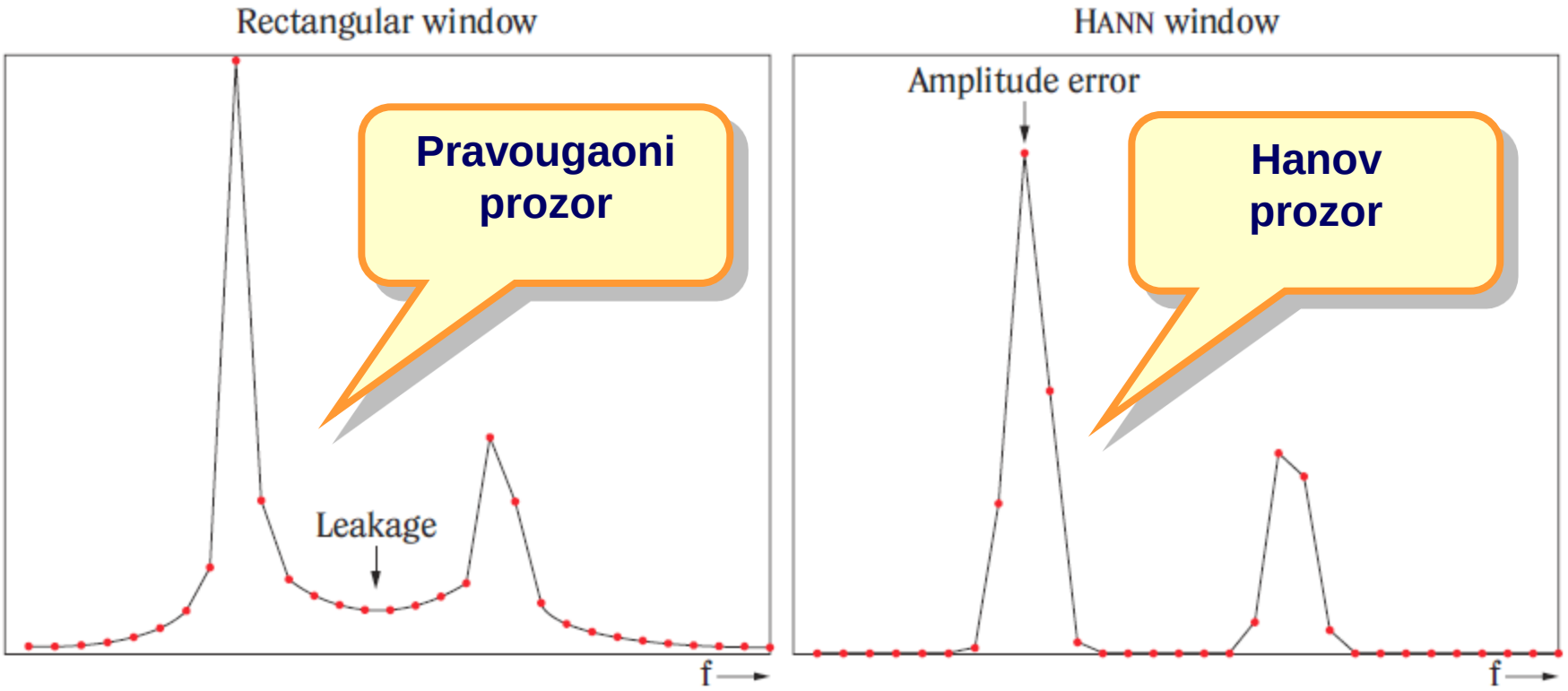

Efekat cirenja

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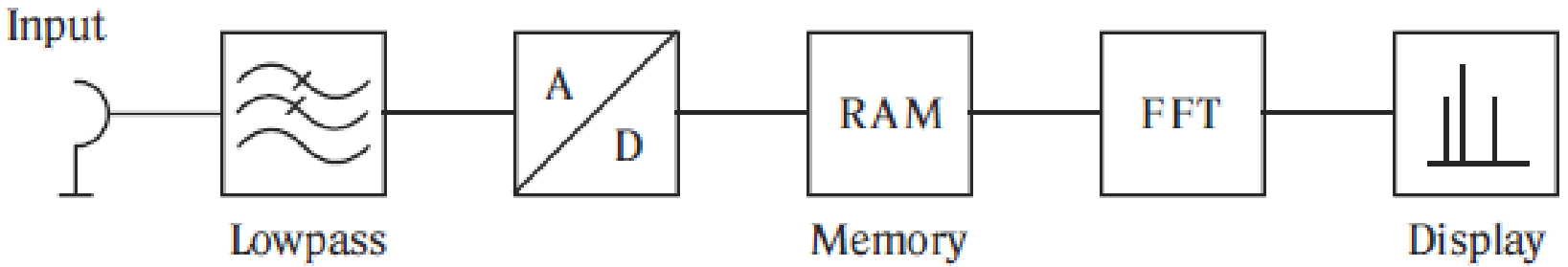
Signal u frekv. domenu i vremenski prozor

✓ Analizator spektra na bazi FFT



Spektar signala kada nije sinusoida beskonačnog trajanja

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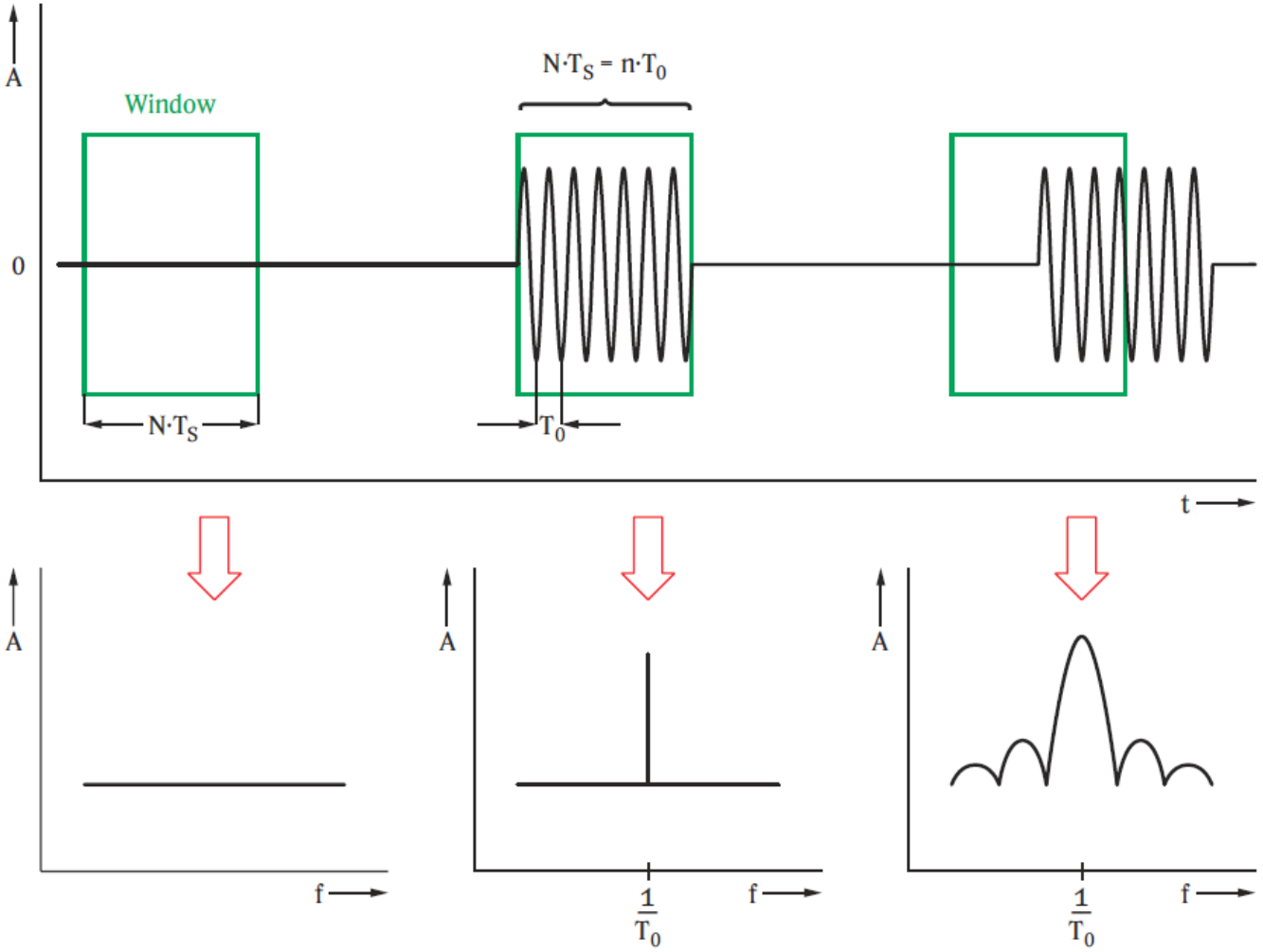
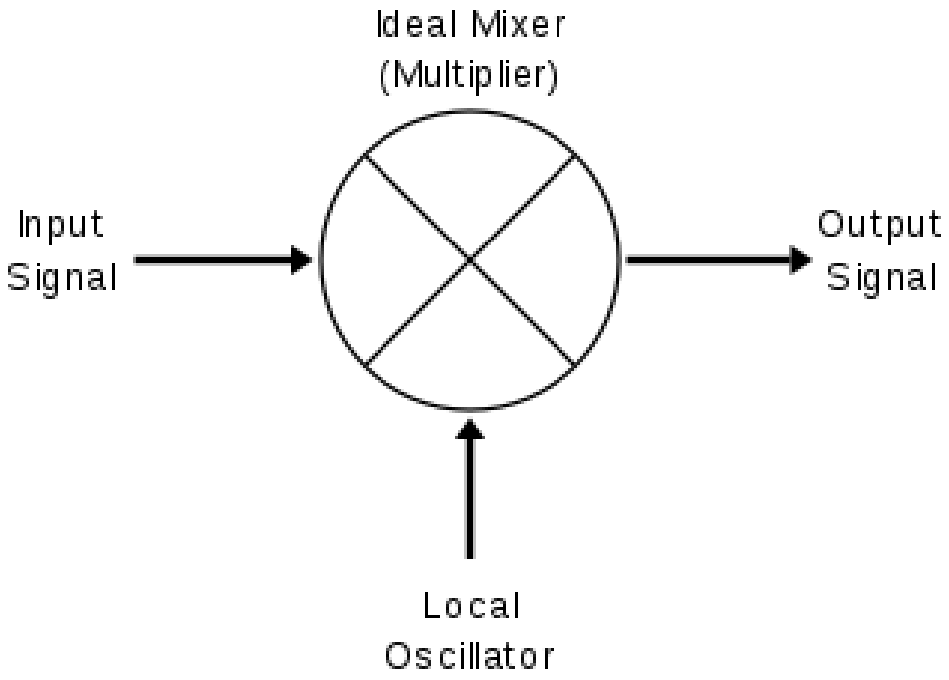
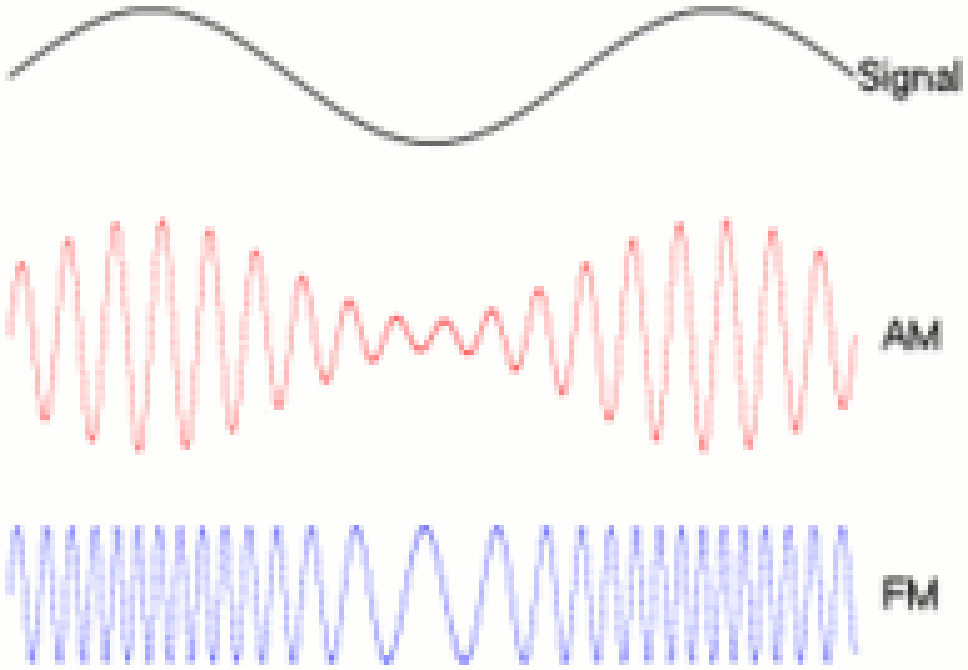


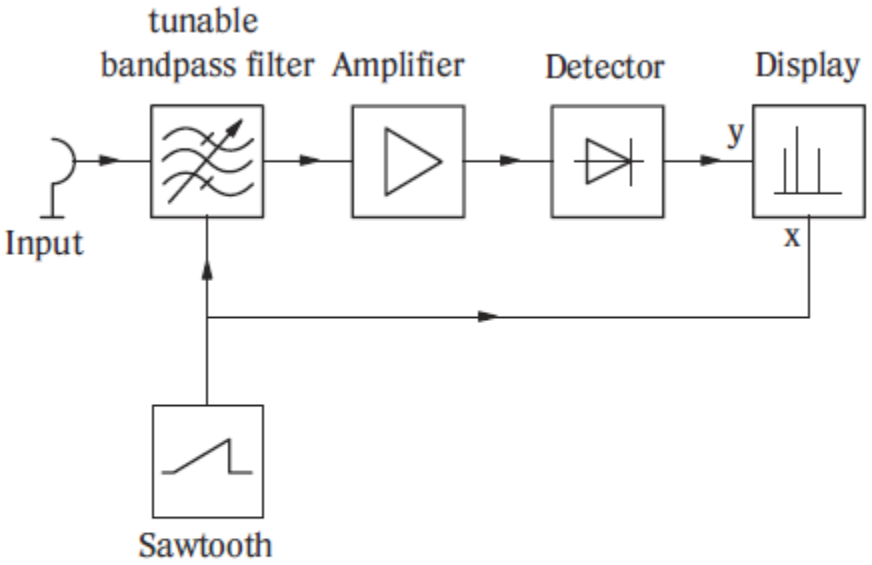
Heterodyning je tehnika obrade signala koja stvara nove učestanosti kombinacijom 2 učestanosti

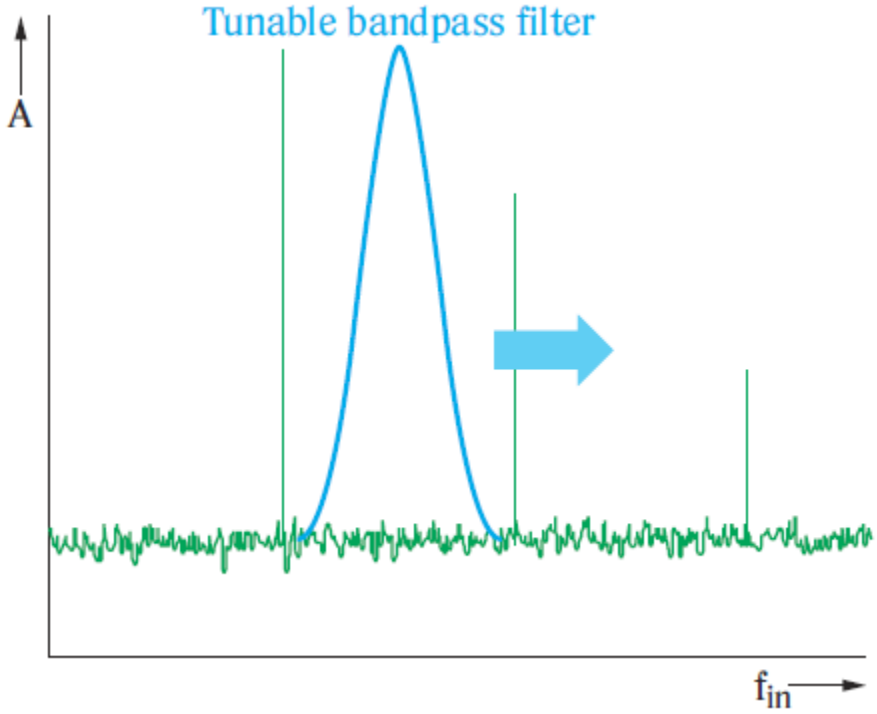


Modulacija je proces u kojem signal informacije menja drugi signal više učestanosti, tzv. nosilac, da bi se prenosio u drugom frekvencijskom opsegu



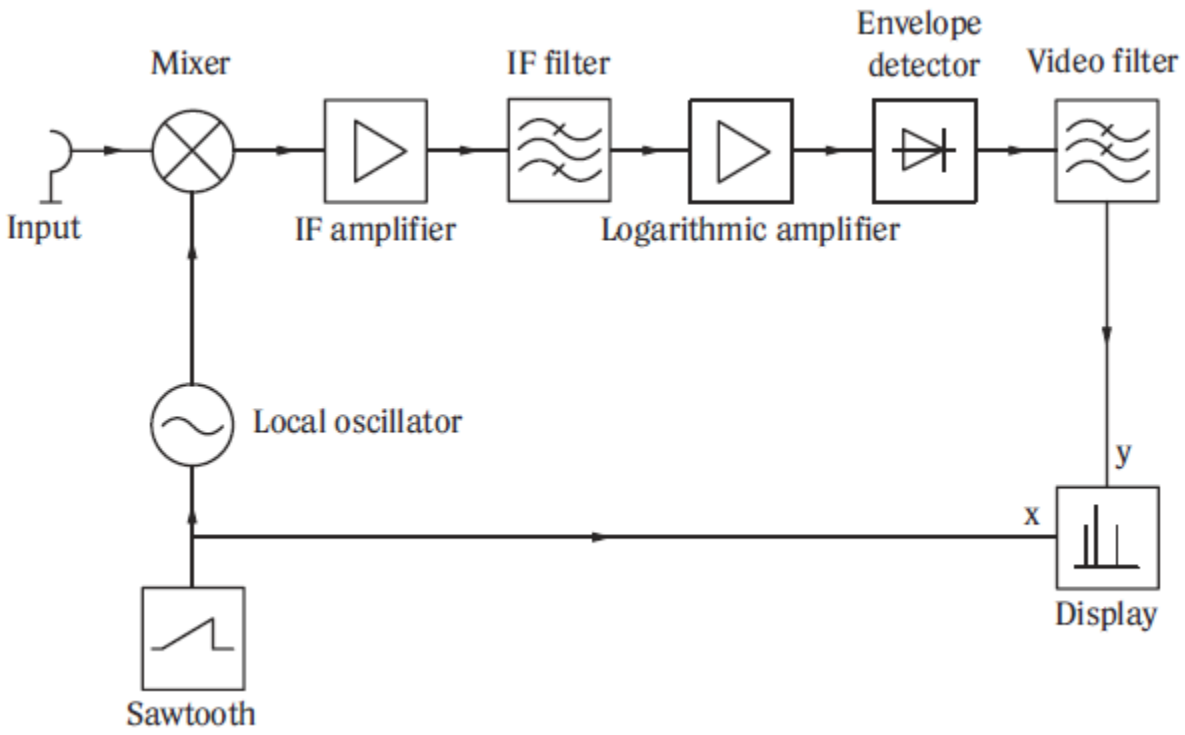
Analiza spektra korišćenjem principa heterodyne





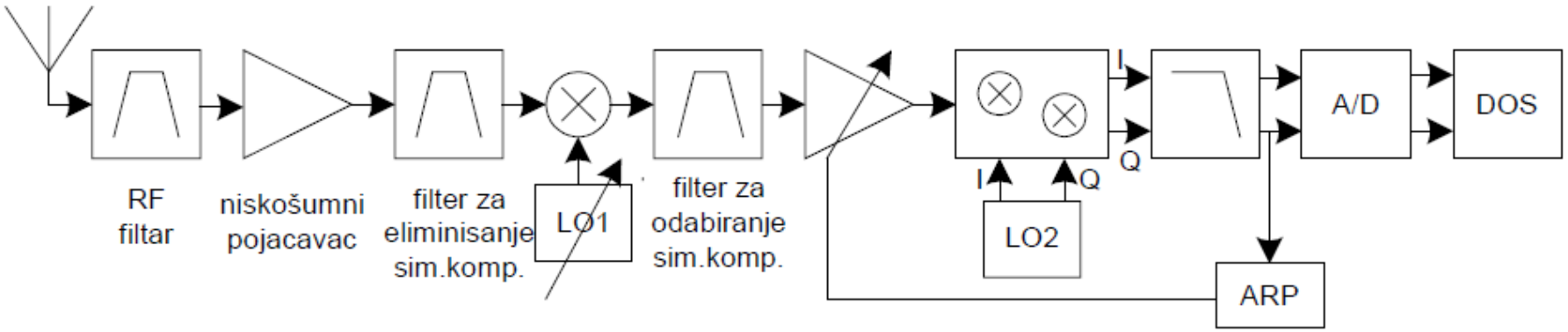
✓ Analizator spektra sa filtrom propusnog opsega koji može da podesi centralnu učestanost

Analiza spektra korišćenjem heterodinskog principa



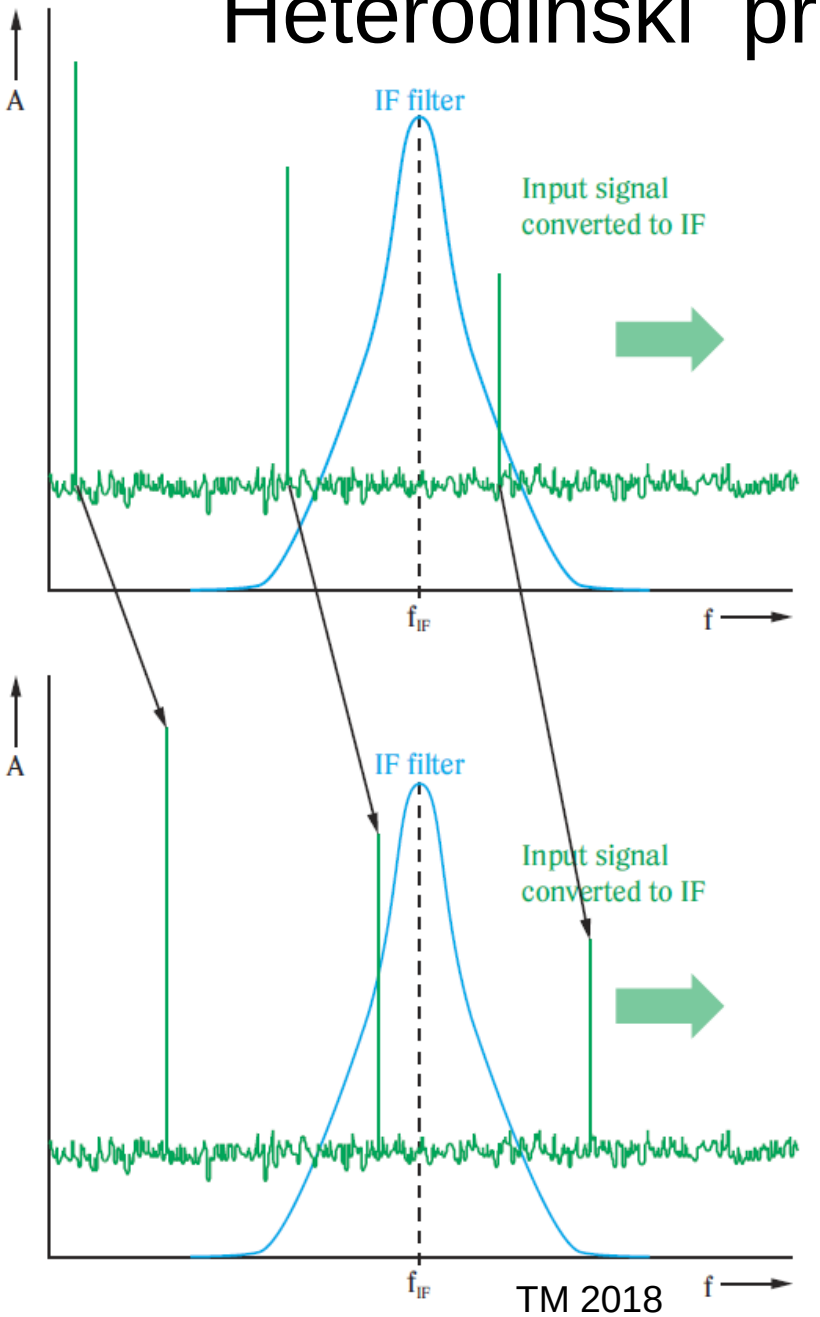
✓ Analizator spektra korišćenjem heterodinskog principa

Princip heterodinskog prijemnika



✓ Blok šema heterodinskog prijamnika

Heterodinski prijemnik



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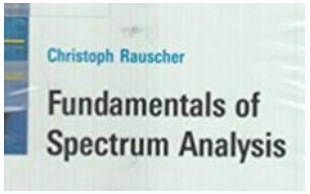
Osnovni parametri za podešavanje



- **Prikaz opsega učestanosti**

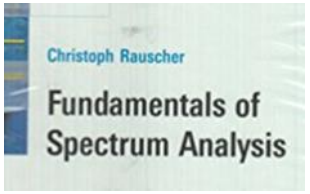
start & stop frequency

➢minimalna i maksimalna učestanost za prikaz

center frequency & the span centered about the center frequency

➢cetralna učestanost i opseg oko centralne učestanosti

Osnovni parametri za podešavanje



- **Opseg prikazivanja nivoa**

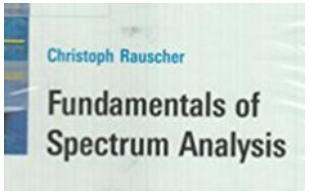
maximum level to be displayed & stop frequency

➢Referentni nivo i opseg za prikaz
na primer referentni nivo 0 dBm i opseg 100 dB

attenuation of an input RF attenuator,
oslabljivač, otporni delitelj,

➢Slabljenje razdelnika na ulazu u RF stepen

Osnovni parametri za podešavanje

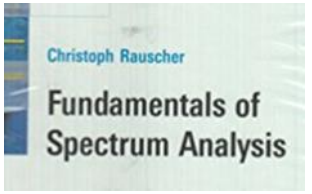


- **Frekvencijska rezolucija**

kada se heterodinski prijemnik
frequency resolution is set via bandwidth of IF filter

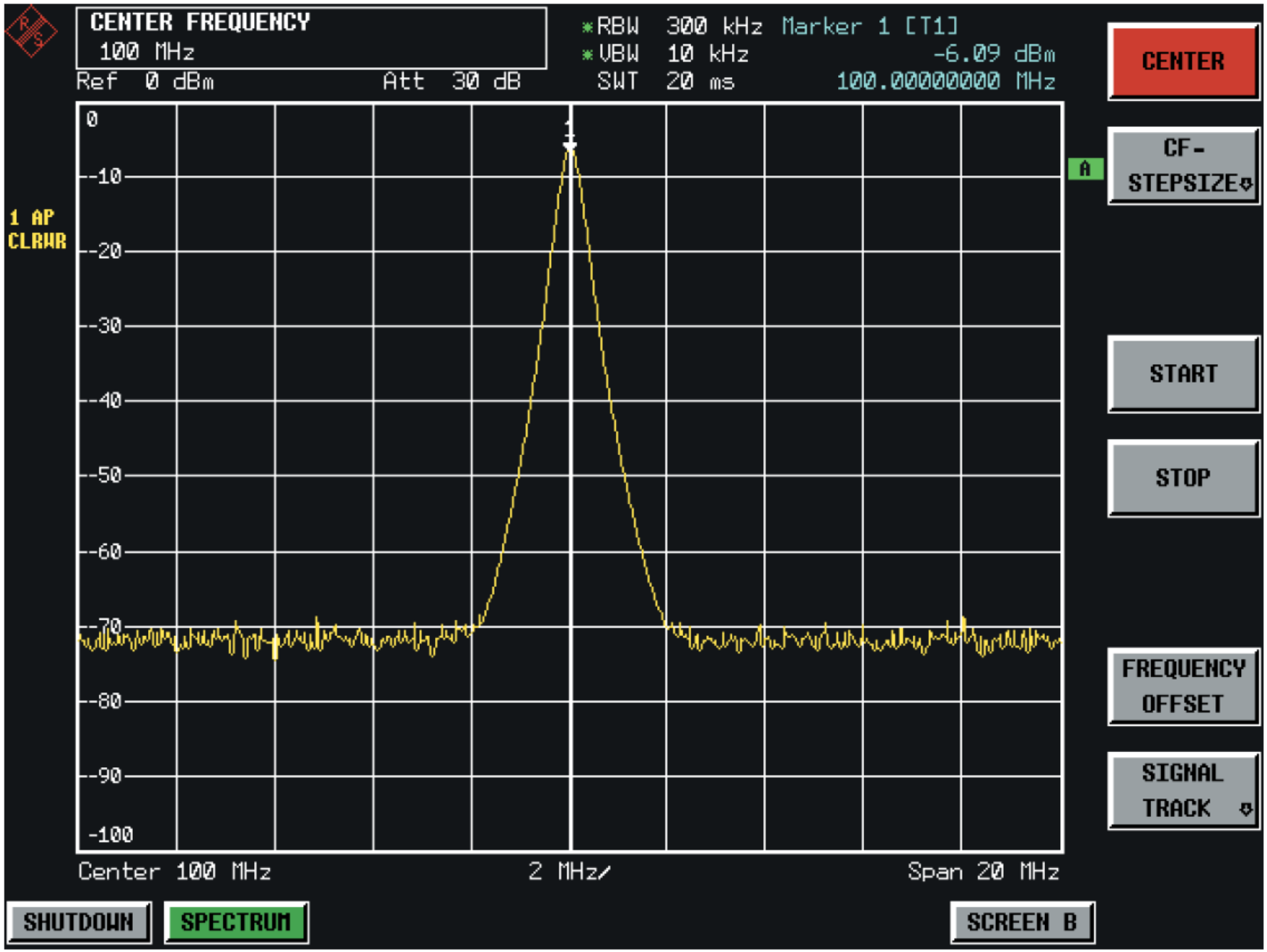
➢resolution bandwidth (RBW)

Osnovni parametri za podešavanje



- **Sweep time (only for analyzers operating on the heterodyne principle)**

  - The time required to record the whole frequency spectrum that is of interest is described as sweep time
  - Very small resolution bandwidths, for instance, call for a correspondingly long sweep time.


CENTER FREQUENCY
100 MHz
Ref 0 dBm
Att 30 dB
RBW 300 kHz
VBW 10 kHz
SWT 20 ms
Marker 1 [T1]
-6.09 dBm
100.00000000 MHz
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
1 AP
CLRWR
A
Center 100 MHz
2 MHz/
Span 20 MHz
CENTER
CF-
STEPSIZE
START
STOP
FREQUENCY
OFFSET
SIGNAL
TRACK
SHUTDOWN
SPECTRUM
SCREEN B

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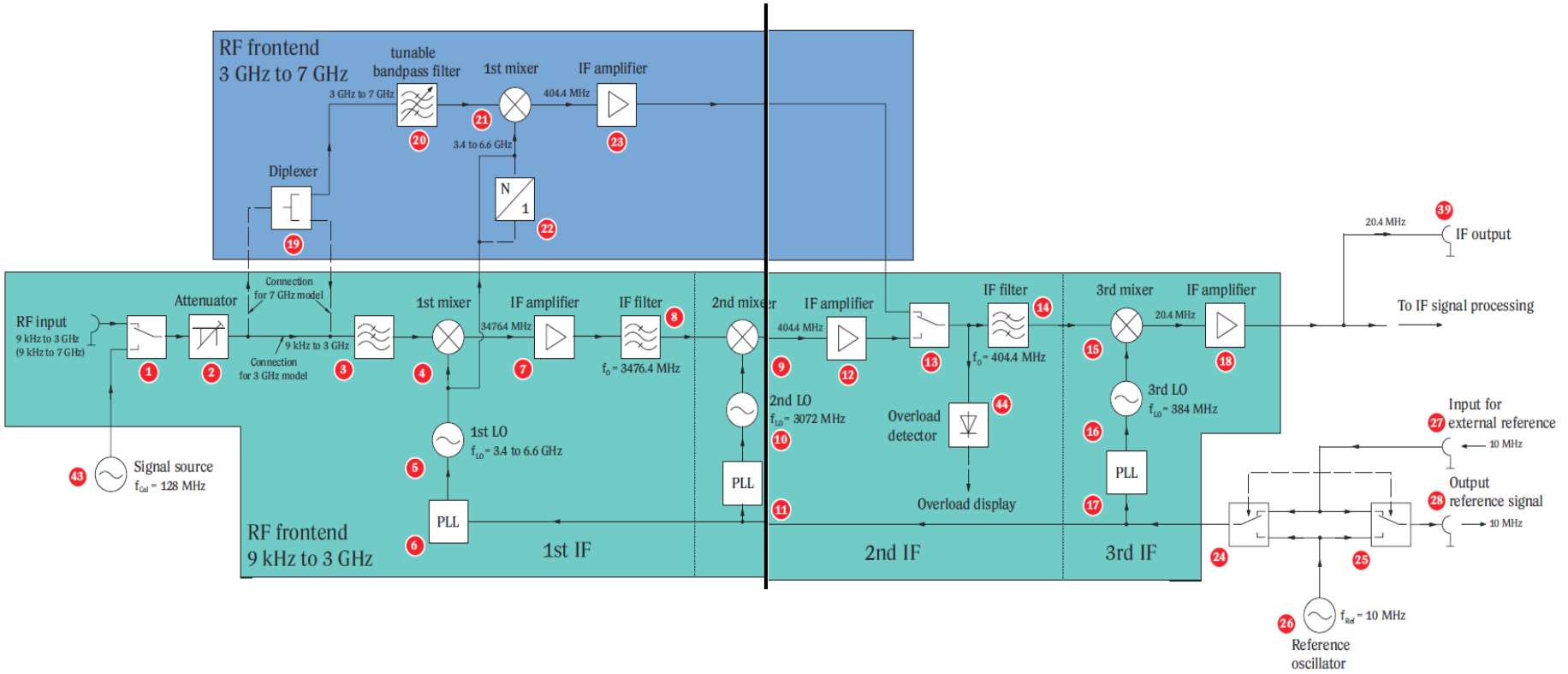
Praktična realizacija

- Savremeni analizator spektra za frekvencijski opseg od 9 kHz do 3 GHz / 7 GHz, heterodinski princip



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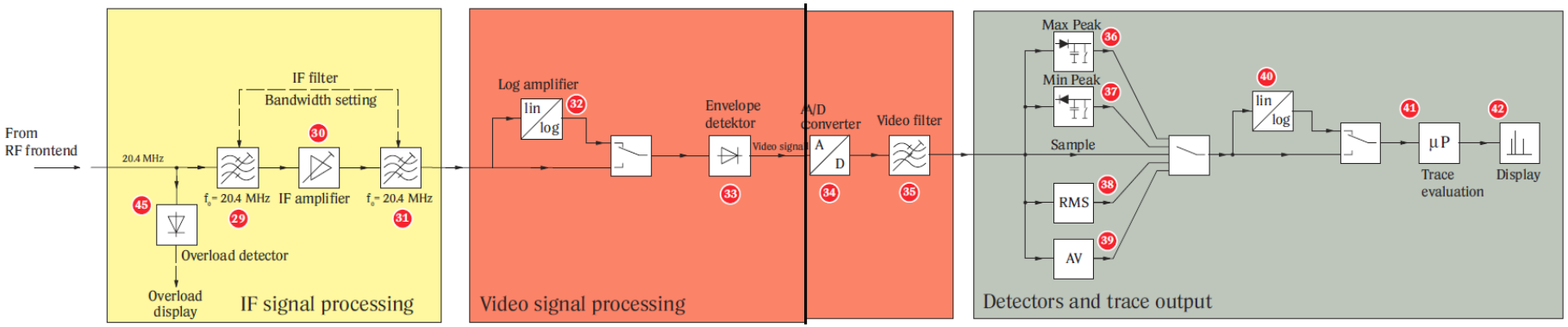
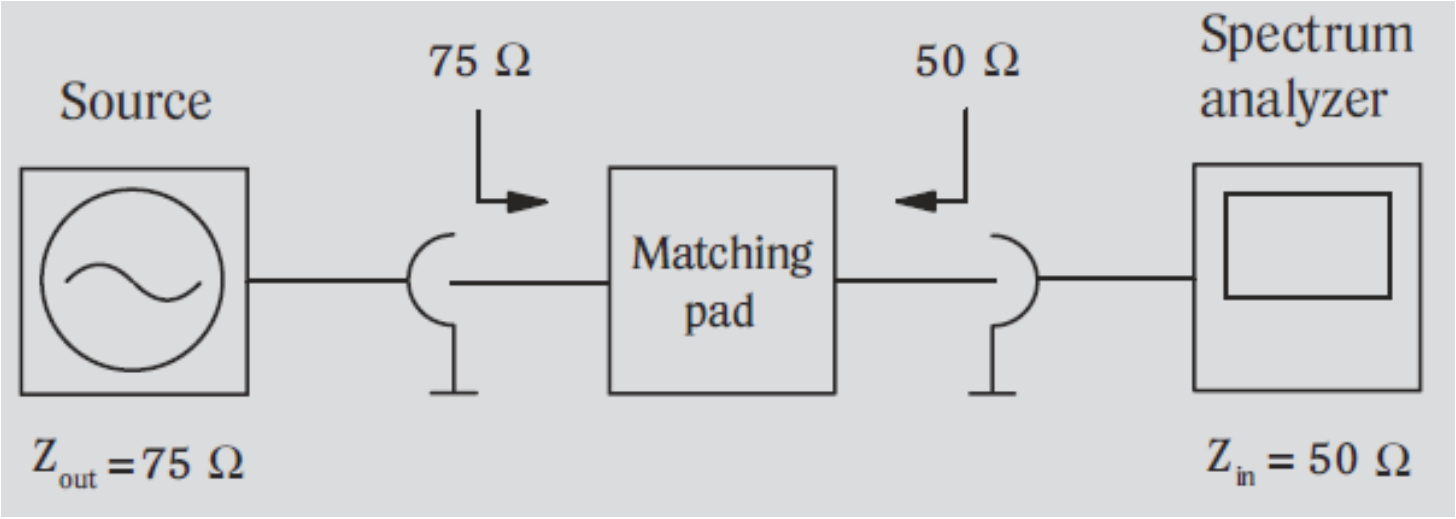


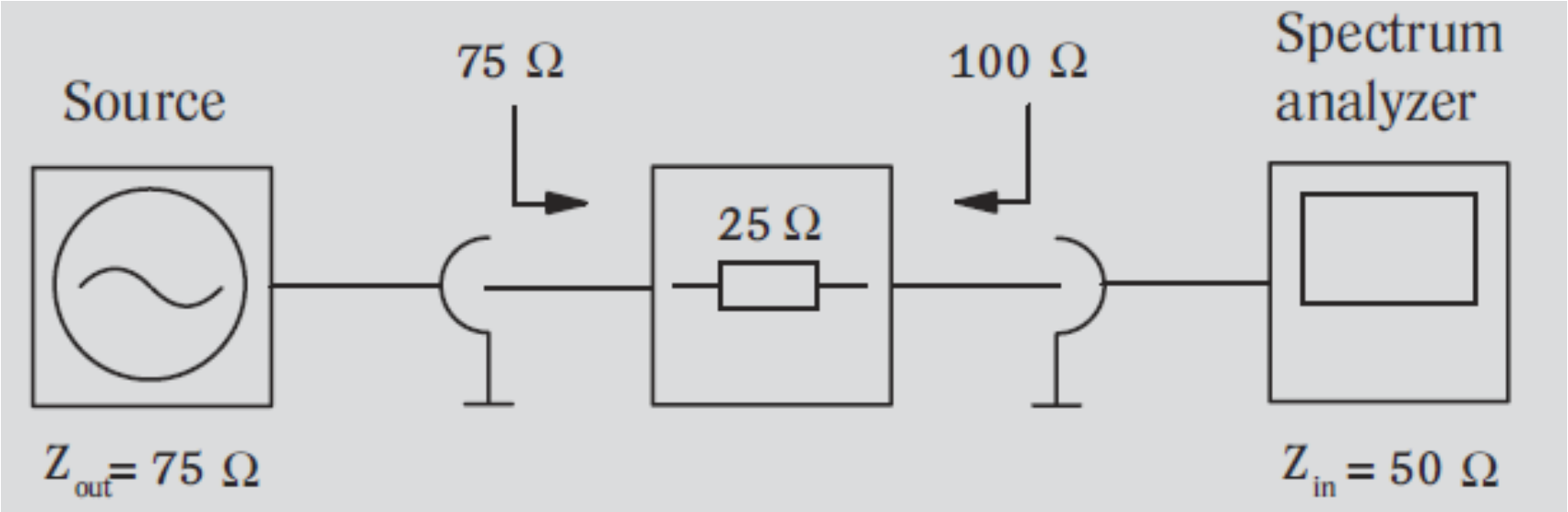
RF input sekcija (frontend)

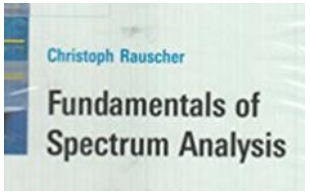
- RF input impedansa 50 Ω
- Za 75 Ω sisteme, kablovski sistemi, (CATV), može da bude i 75 Ω input impedanse
- Transformator impedanse, analizator sa ulaznih 50 Ω može da se koristi i za 75 Ω sistem



RF input sekcija (frontend)

- RF input impedansa 50 Ω

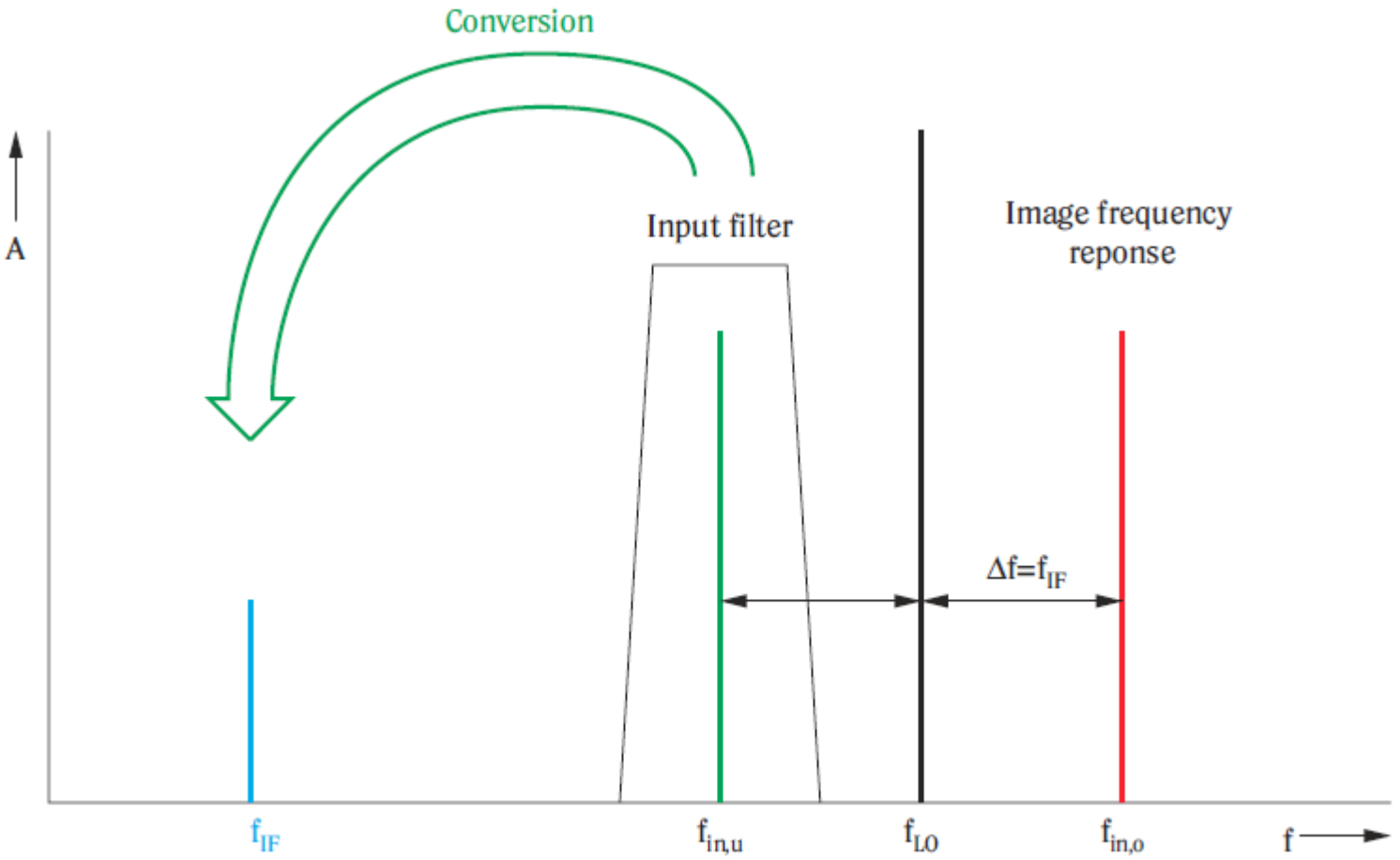




RF attenuation

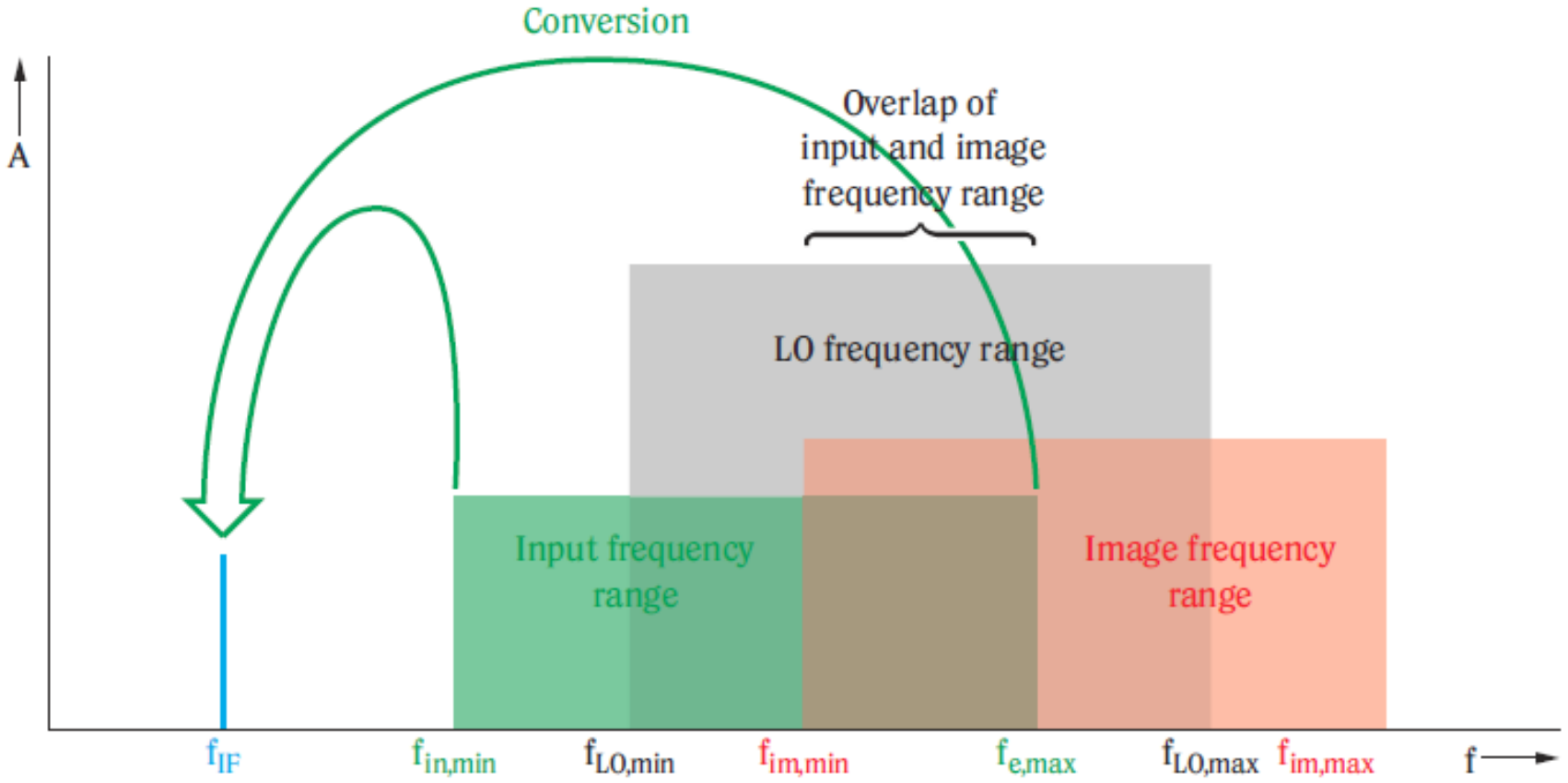
- Slabljenje se podešava u koracima 10 dB
- Za finija podešavanja, u preciznijim koracima od 5 dB ili 1 dB

Dvosmislenost heterodinskog principa

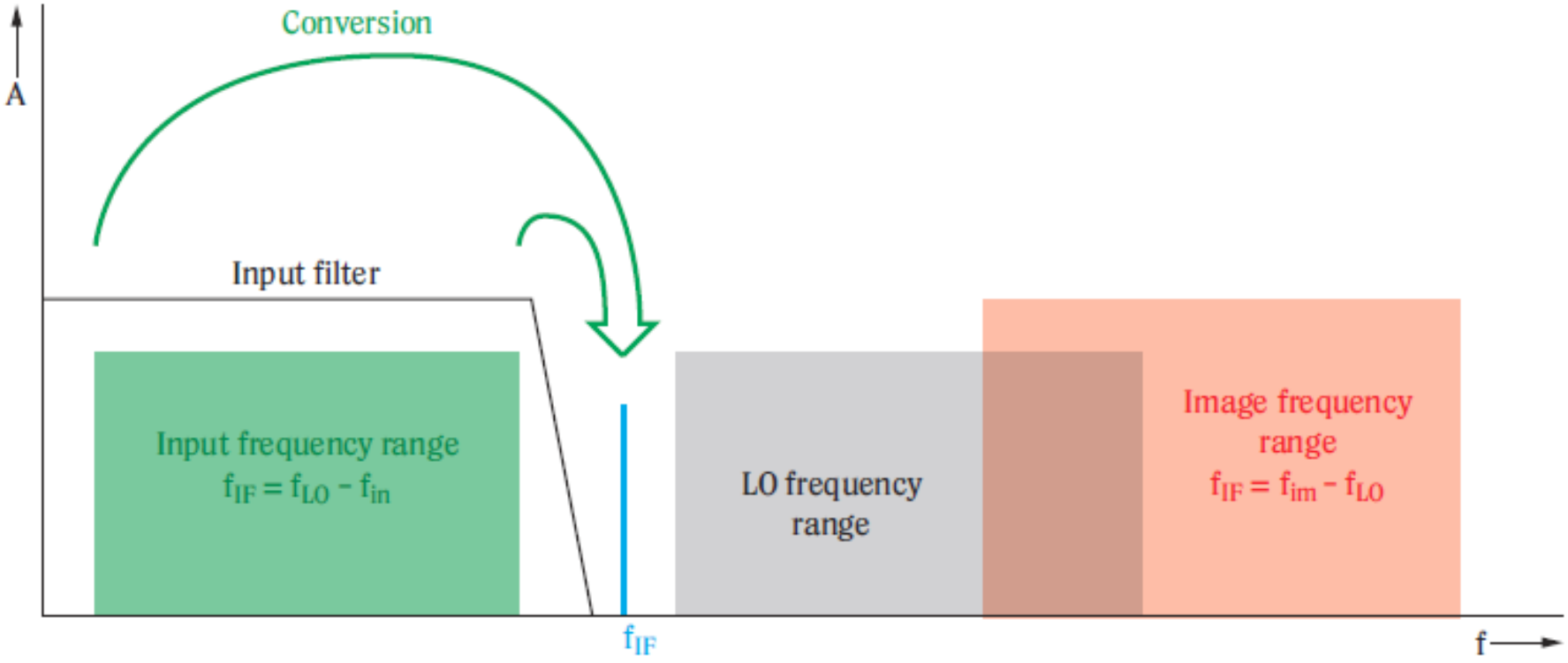


Preklapanje heterodinskog principa

Christoph Rauscher
Fundamentals of Spectrum Analysis

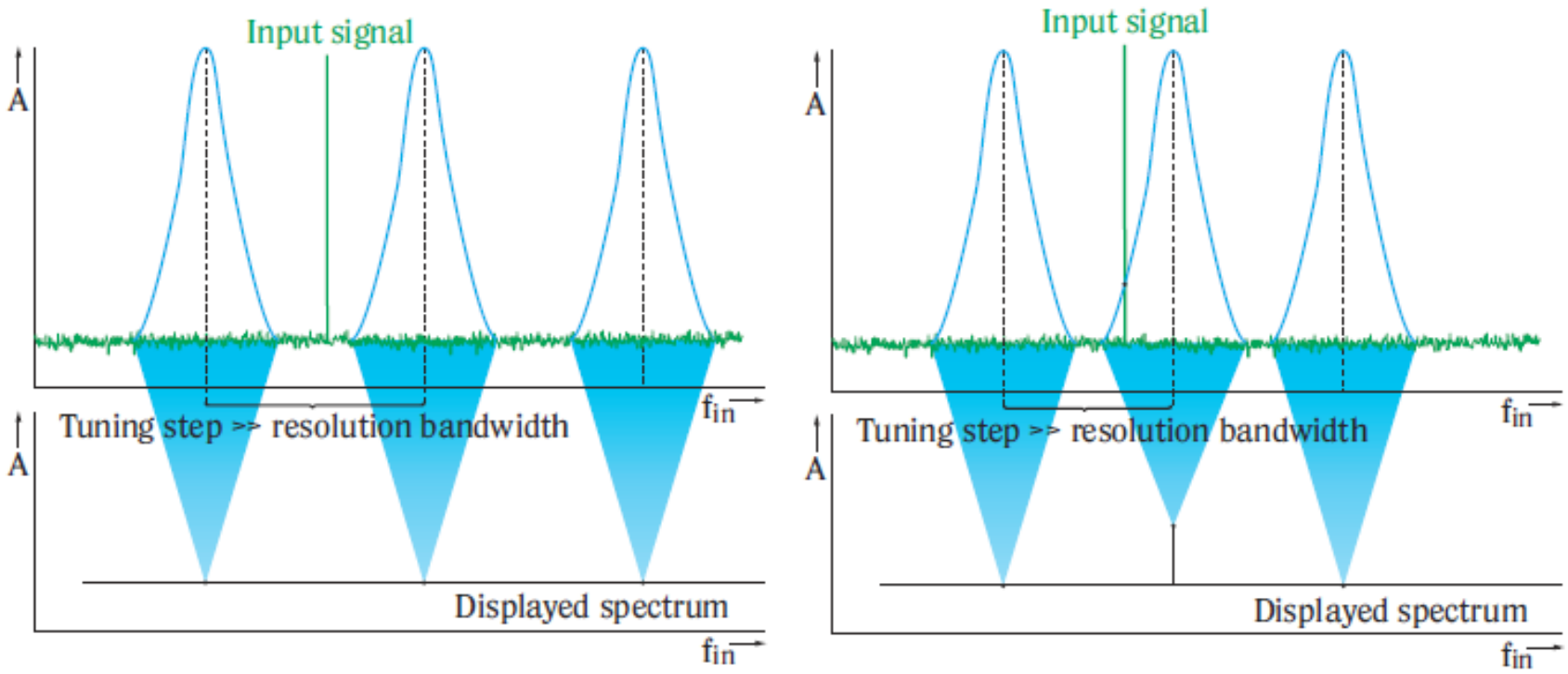


High intermediate frequency
Visoka međufrekvencija

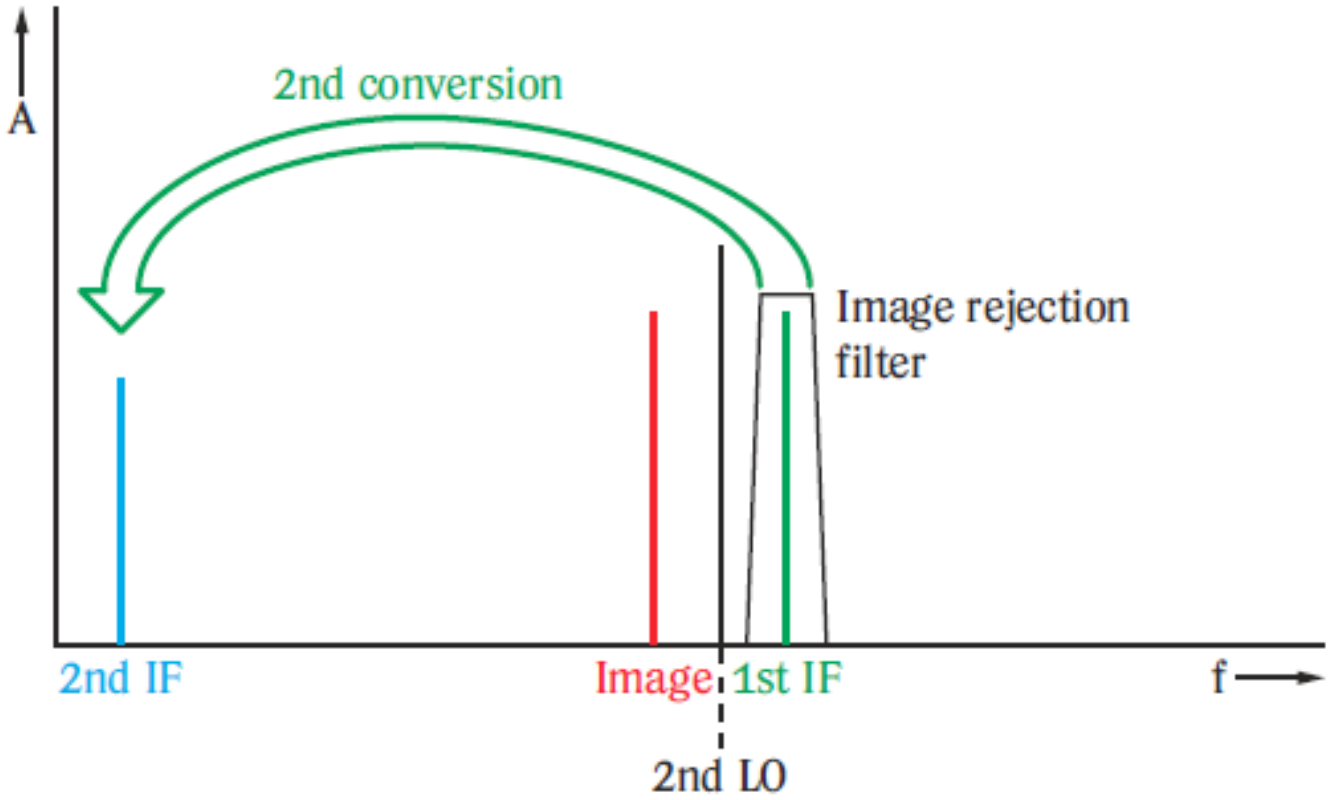


Veliki koraci podešavanje koraka

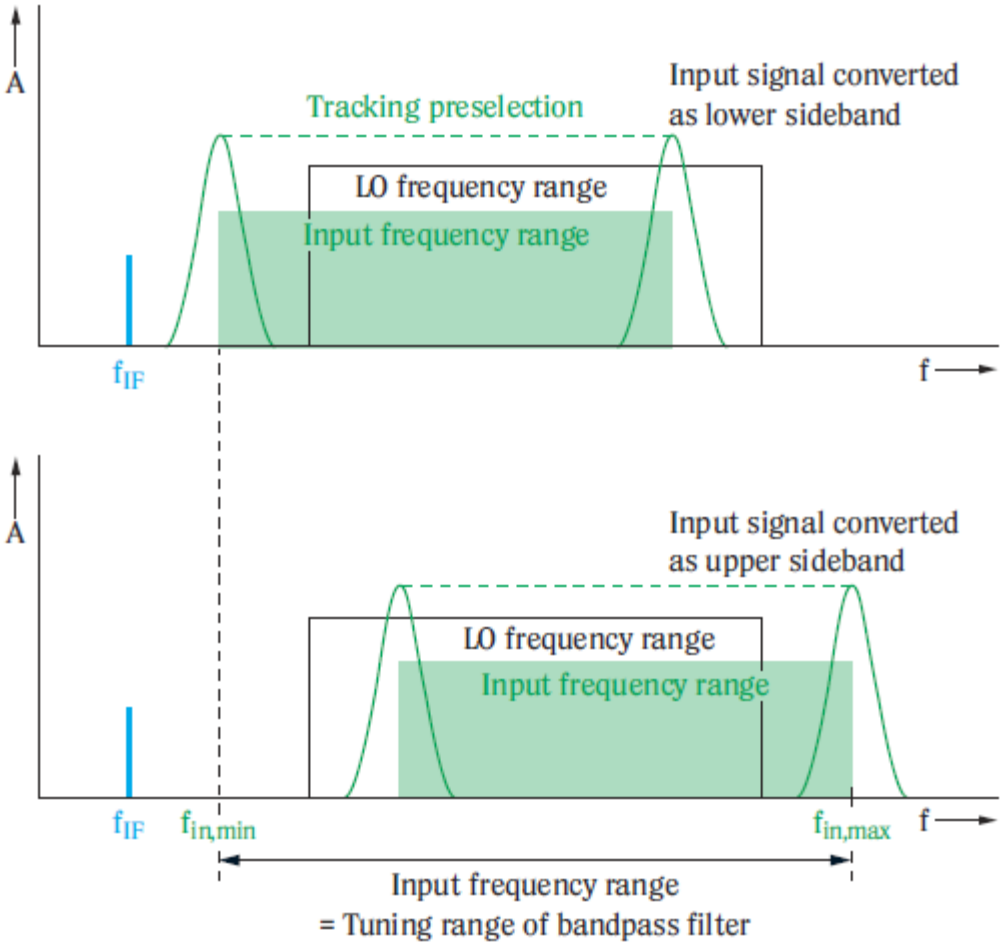
Christoph Rauscher
Fundamentals of Spectrum Analysis



Konverzija visoke 1. IF u nisku 2. IF



Konverzija u nisku IF 46



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