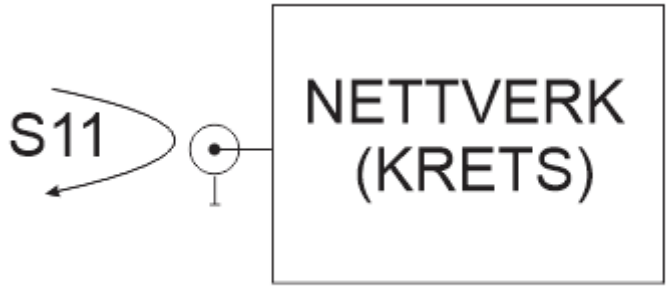
Nettverksanalysatorer

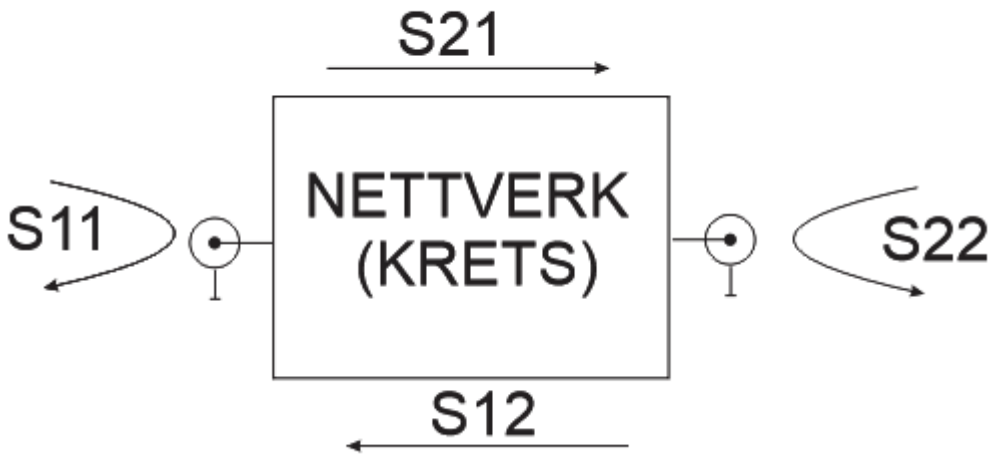
NanoVNA og andre uhumskheter

LA3PNA 2025

Hva er en nettverksanalysator?

- Hva er ett nettverk?





Nettverksanalysatoren analyserer nettverk

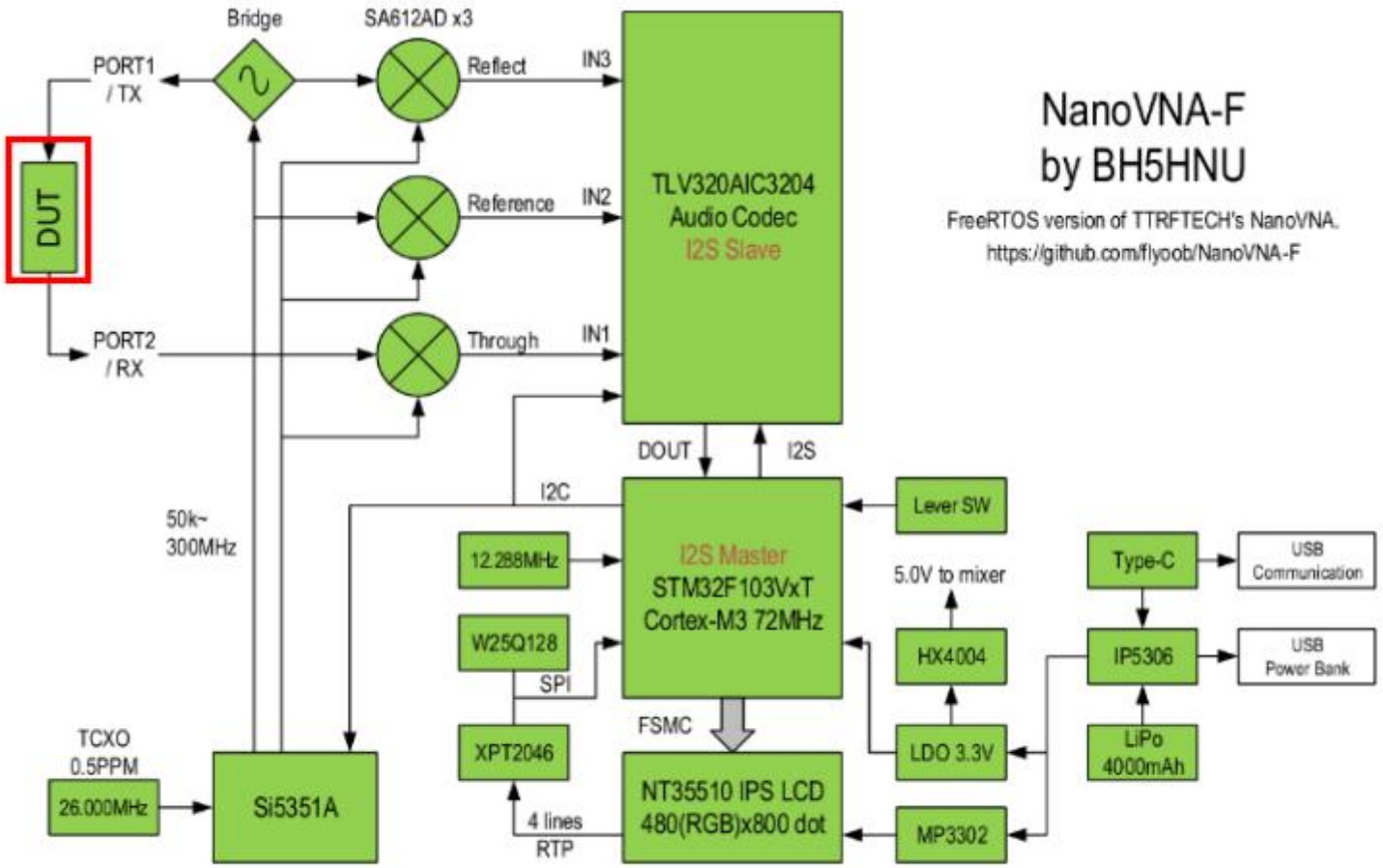
- En port (S11) - Impedans
- 2-port (S11, S12, S21, S22) – Impedans og transmisjonsparameter
- Impedans er normalt målt som refleksjonskoeffesient, og regnes om til ohm eller VSWR.
- Transmisjonsparameter er enten linjær (proposjonal med spenning) eller dB.
- Normalt bruker vi normaliserte impedanser (maks tilpasning =1)

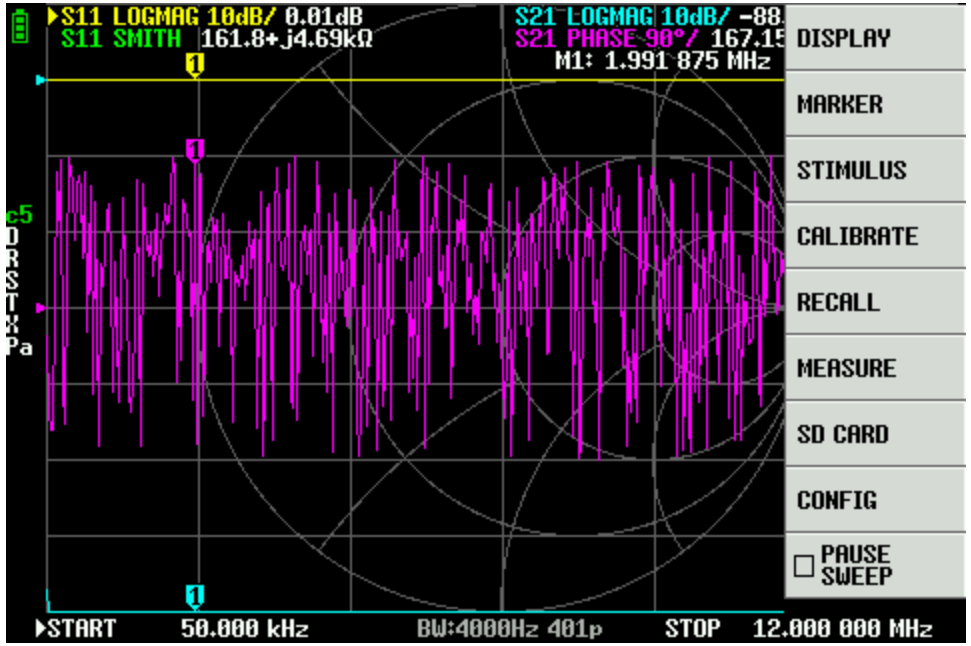
- Du kan ha så mange parametere du har porter, for eksempel har en BALUN ofte 3 porter.

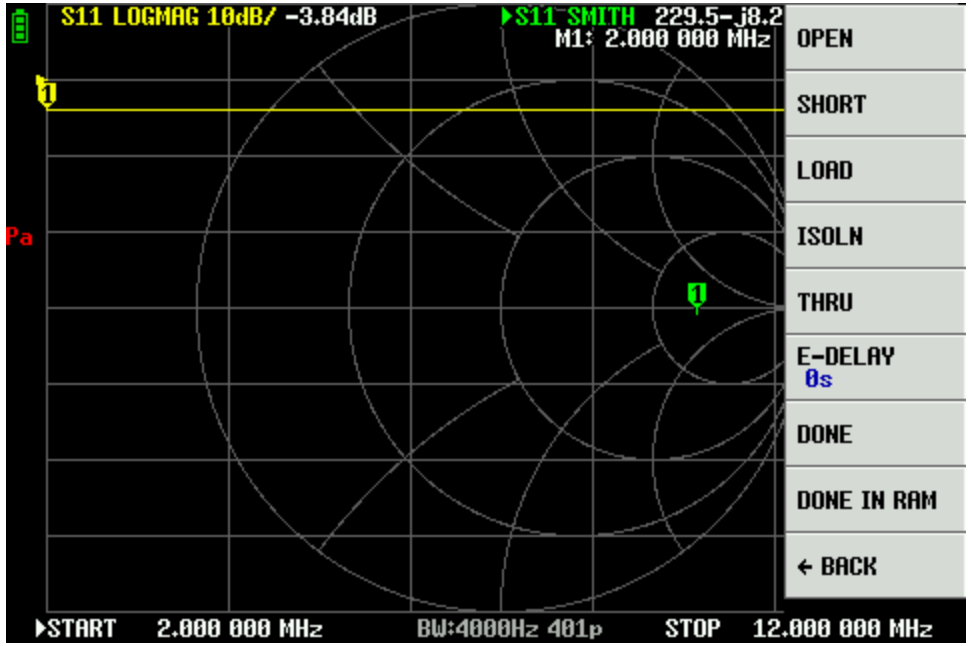
SDR-Kits
1 kHz - 1.3 GHz
TX Out
RX In
DG8SAQ Vector Network Analyzer v3

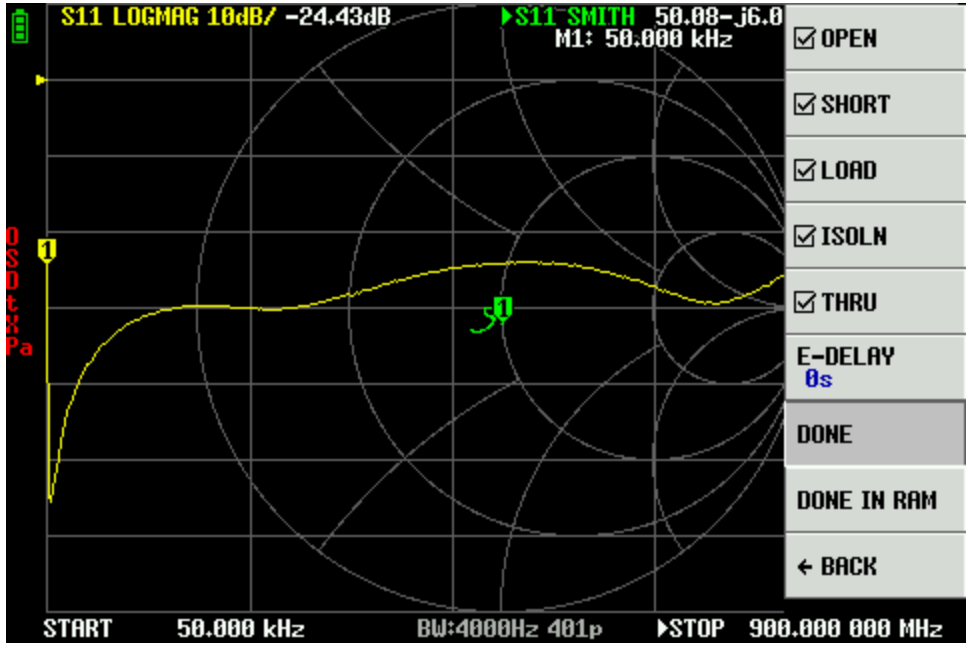
PORT1
S11
+10dBm RF
10VDC Max
S21
PORT2
S11 SMITH 47.35+j4.662Ω
M1: 99.833 500 MHz
NanoVNA

8418A-H01 AUXILIARY DISPLAY HOLDER
HEWLETT-PACKARD
MTS no1
8410C NETWORK ANALYZER
HEWLETT-PACKARD
8412A PHASE-MAGNITUDE DISPLAY
HEWLETT-PACKARD
CALIBRATE BEFORE USE
8743B OPT 018 REFLECTION-TRANSMISSION TEST UNIT 2.0-18.0 GHz
HEWLETT-PACKARD
REFERENCE PLANE EXTENSION (CM)
FUNCTION
REFL
TRANS
CALIBRATION NOT REQUIRED
UNKNOWN
TRANSMISSION RETURN
8350A SWEEP OSCILLATOR
HEWLETT-PACKARD
83592A RF PLUG-IN


NanoVNA-F
by BH5HNU
FreeRTOS version of TTRFTECH's NanoVNA.
https://github.com/flyoob/NanoVNA-F
Bridge
SA612AD x3
PORT1
/ TX
DUT
PORT2
/ RX
Reflect
Reference
Through
IN3
IN2
IN1
TLV320AIC3204
Audio Codec
I2S Slave
DOUT
I2S
I2C
50k~
300MHz
12.288MHz
W25Q128
SPI
XPT2046
4 lines
RTP
I2S Master
STM32F103VxT
Cortex-M3 72MHz
FSMC
NT35510 IPS LCD
480(RGB)x800 dot
Lever SW
5.0V to mixer
HX4004
LDO 3.3V
MP3302
Type-C
USB
Communication
IP5306
USB
Power Bank
LiPo
4000mAh
TCXO
0.5PPM
26.000MHz
Si5351A

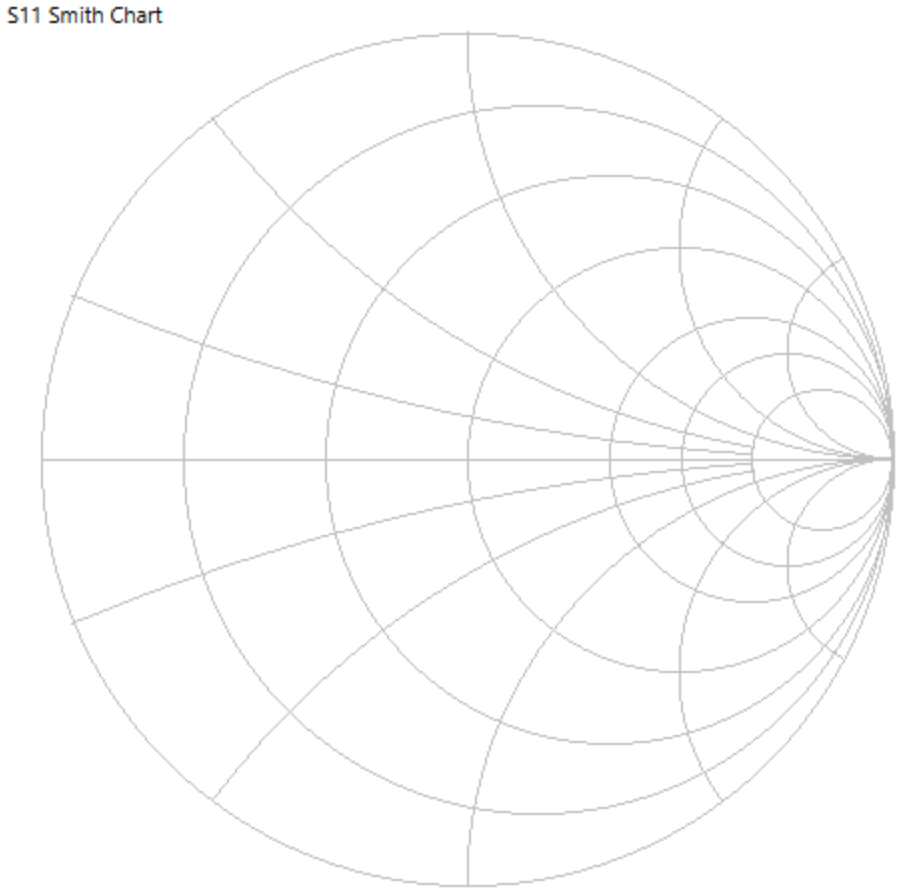

S11 LOGMAG 10dB/ 0.01dB
S11 SMITH 161.8+j4.69kΩ
S21 LOGMAG 10dB/ -88.
S21 PHASE 90°/ 167.15
M1: 1.991 875 MHz
DISPLAY
MARKER
STIMULUS
CALIBRATE
RECALL
MEASURE
SD CARD
CONFIG
PAUSE SWEEP
START 50.000 kHz
BW:4000Hz 401p
STOP 12.000 000 MHz

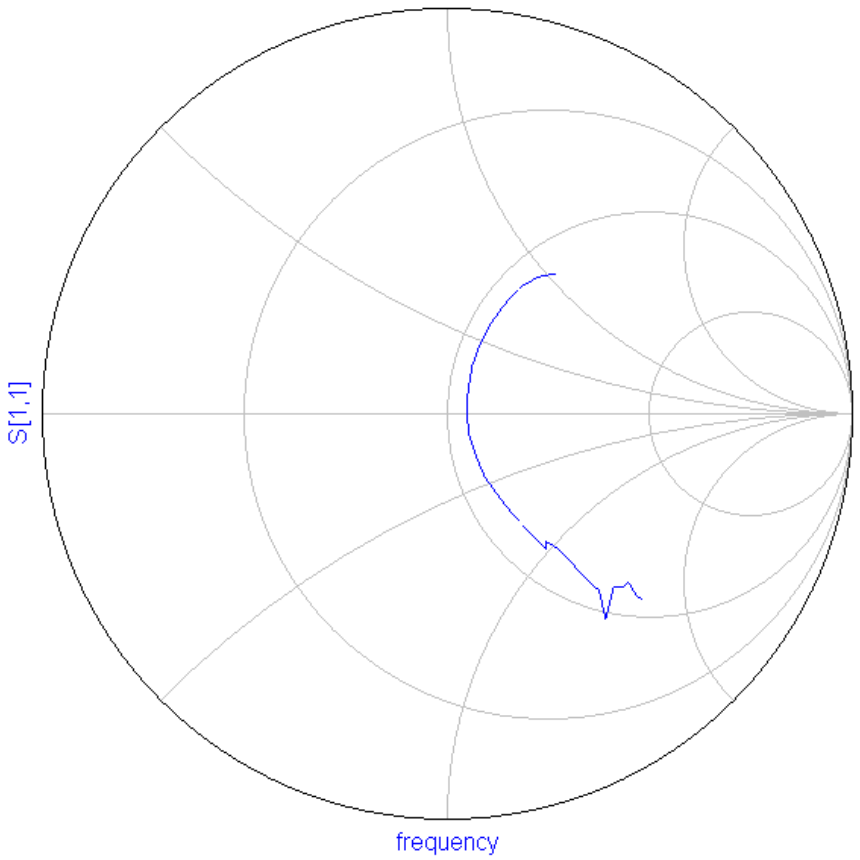

S11 LOGMAG 10dB/ -3.84dB
S11 SMITH 229.5-j8.2
M1: 2.000 000 MHz
OPEN
SHORT
LOAD
ISOLN
THRU
E-DELAY 0s
DONE
DONE IN RAM
← BACK
START 2.000 000 MHz
BW:4000Hz 401p
STOP 12.000 000 MHz


S11 LOGMAG 10dB/ -24.43dB
S11 SMITH 50.08-j6.0
M1: 50.000 kHz
OPEN
SHORT
LOAD
ISOLN
THRU
E-DELAY 0s
DONE
DONE IN RAM
← BACK
START 50.000 kHz
BW:4000Hz 401p
STOP 900.000 000 MHz

Smith diagrammet

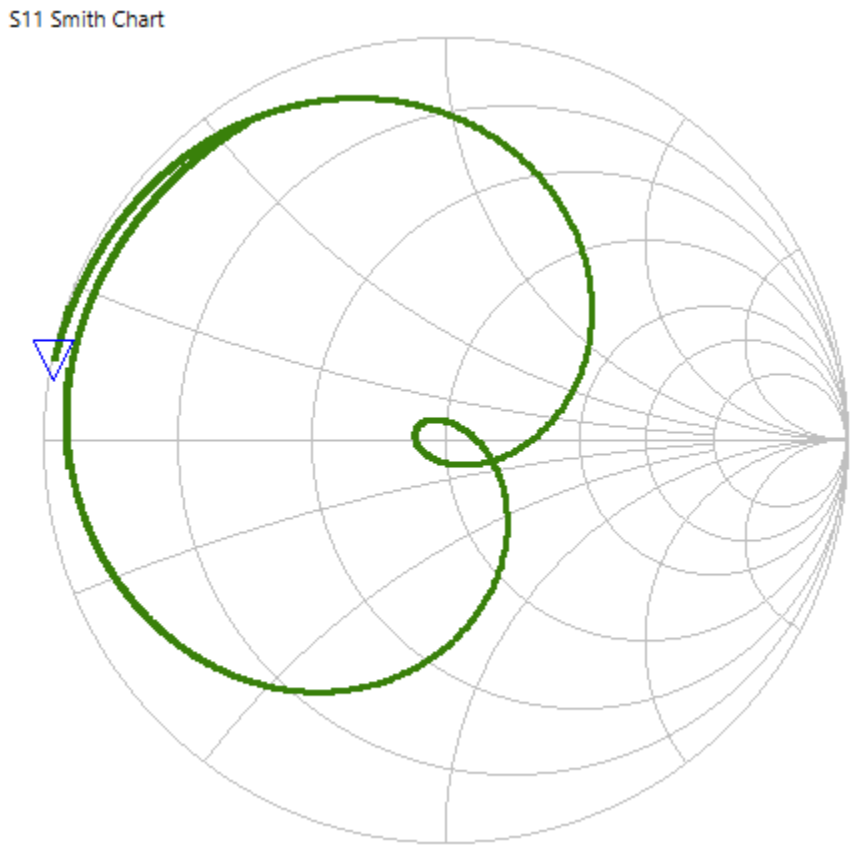
- Måte å vise alle reelle (positive) impedanser





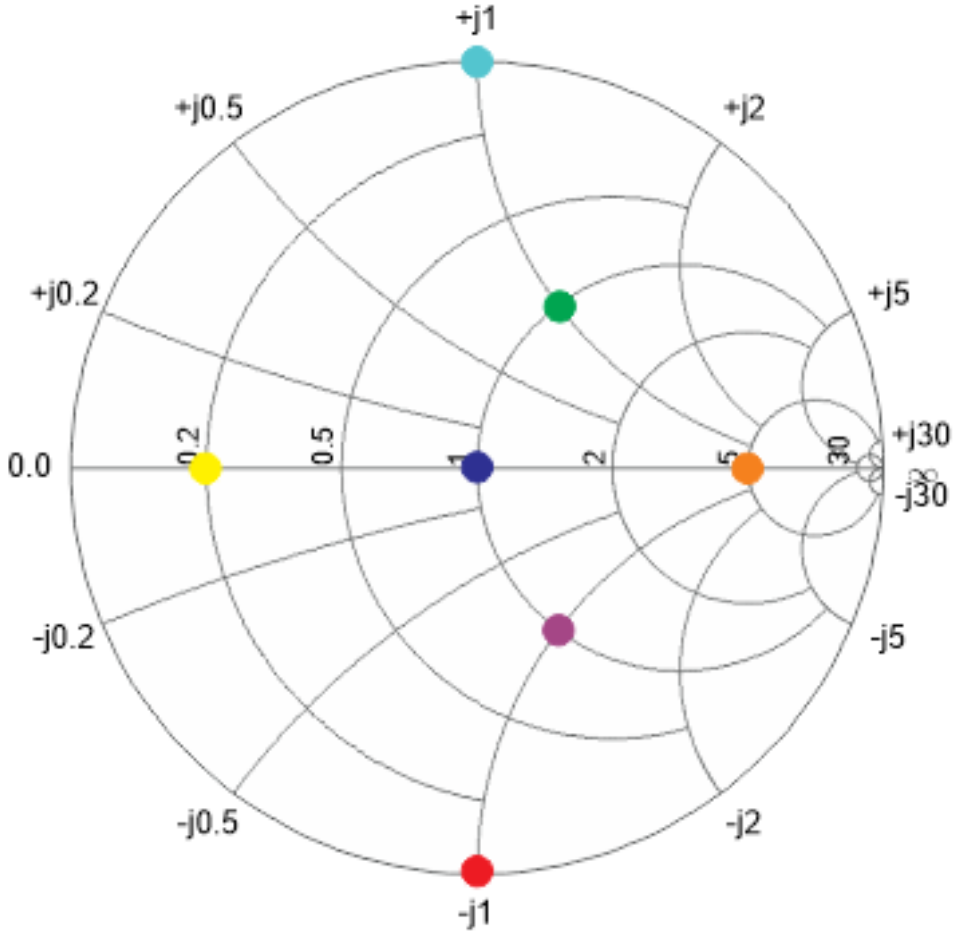
Smith diagrammet

- 50ohm i senter
- Åpen på høyre side
- Kortsluttet på venstre side
- Induktiv «oppover»
- Kapasitiv «nedover»
- Resonans hver gang vi paserer senterlinjen!



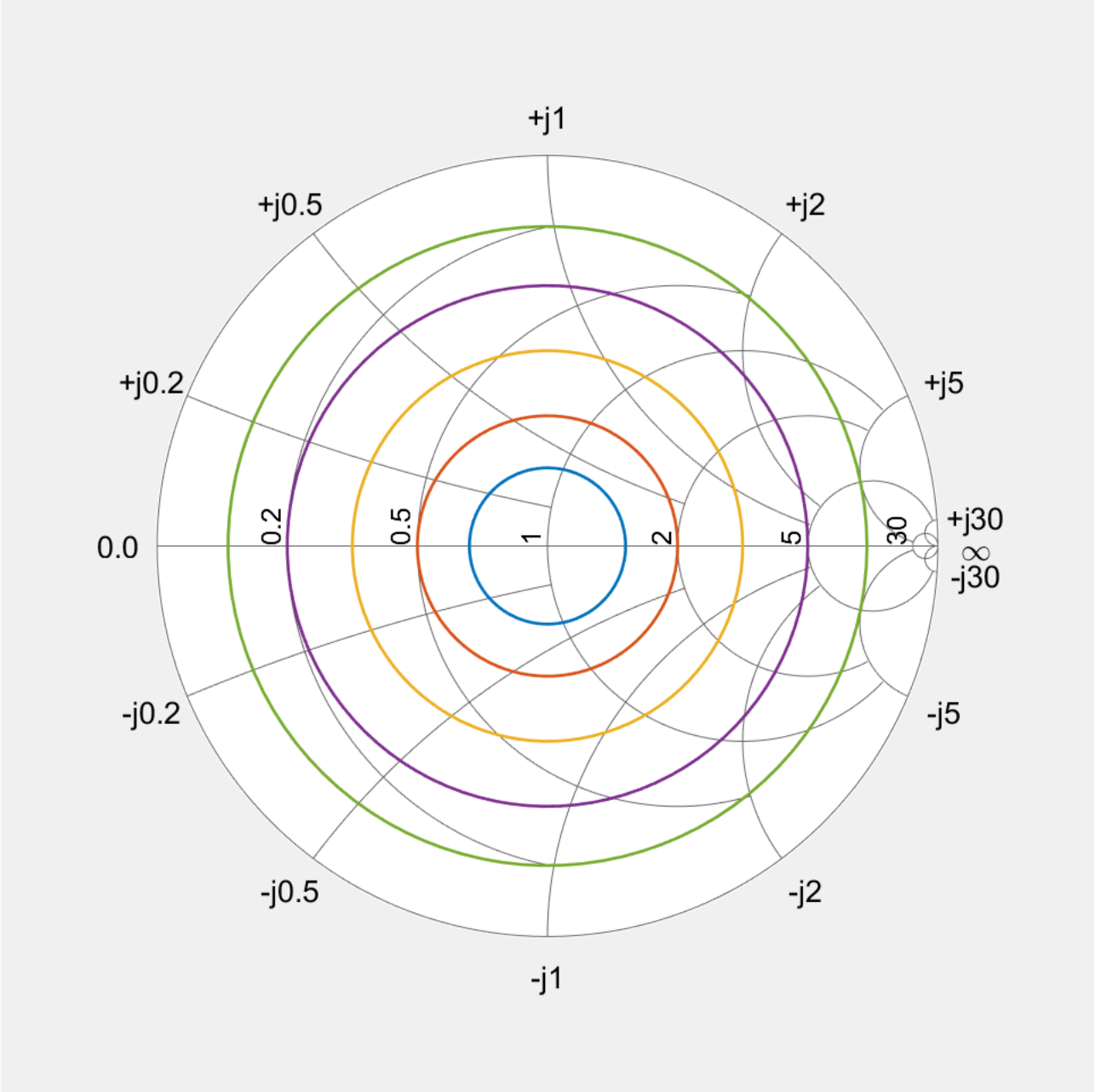
La oss sette inn litt impedanser

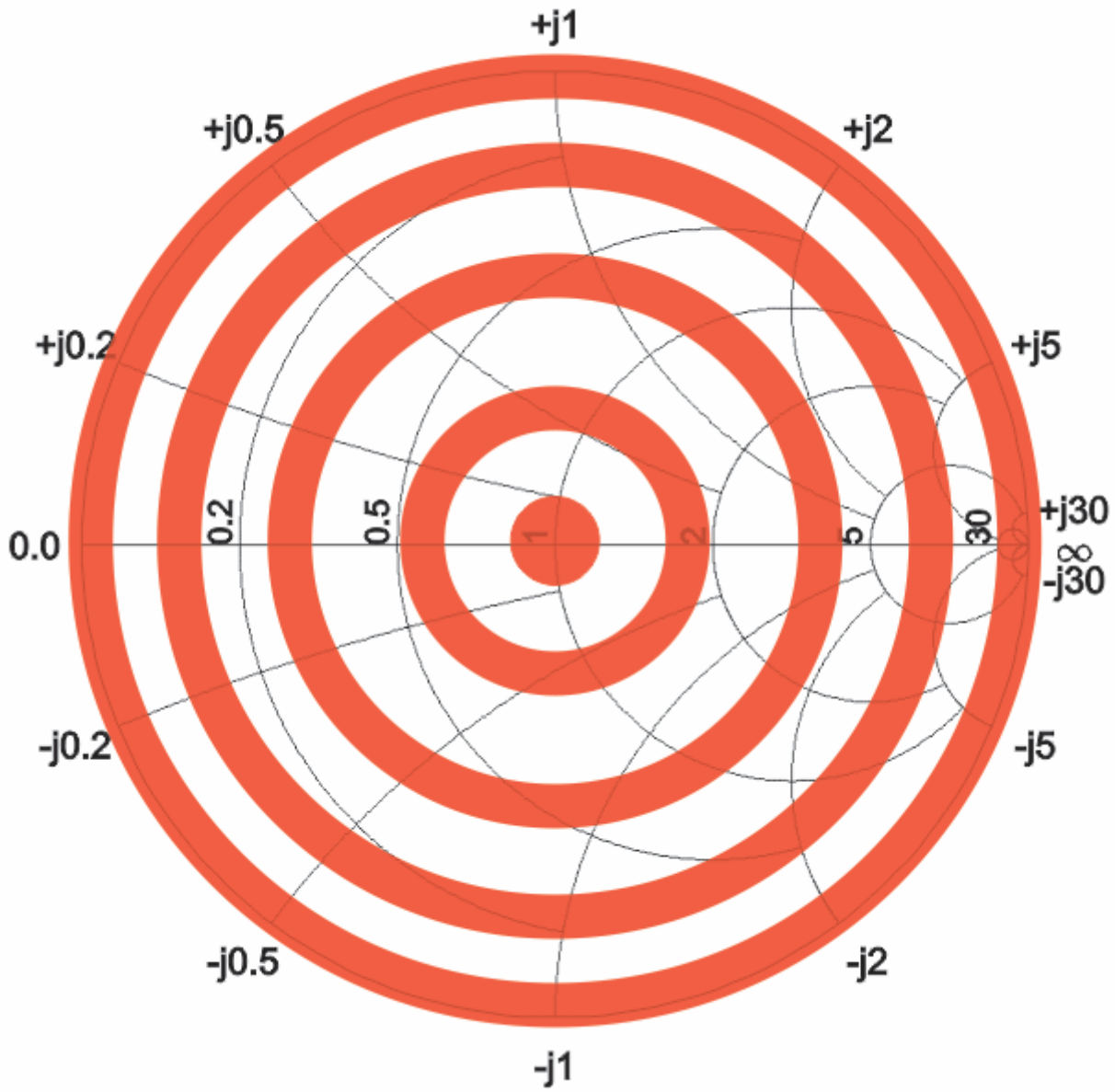
- 50+0j
- 250-0j
- 10+0j
- 50-50j
- 50+50j
- 0-50j
- 0+50j



SWR sirkler

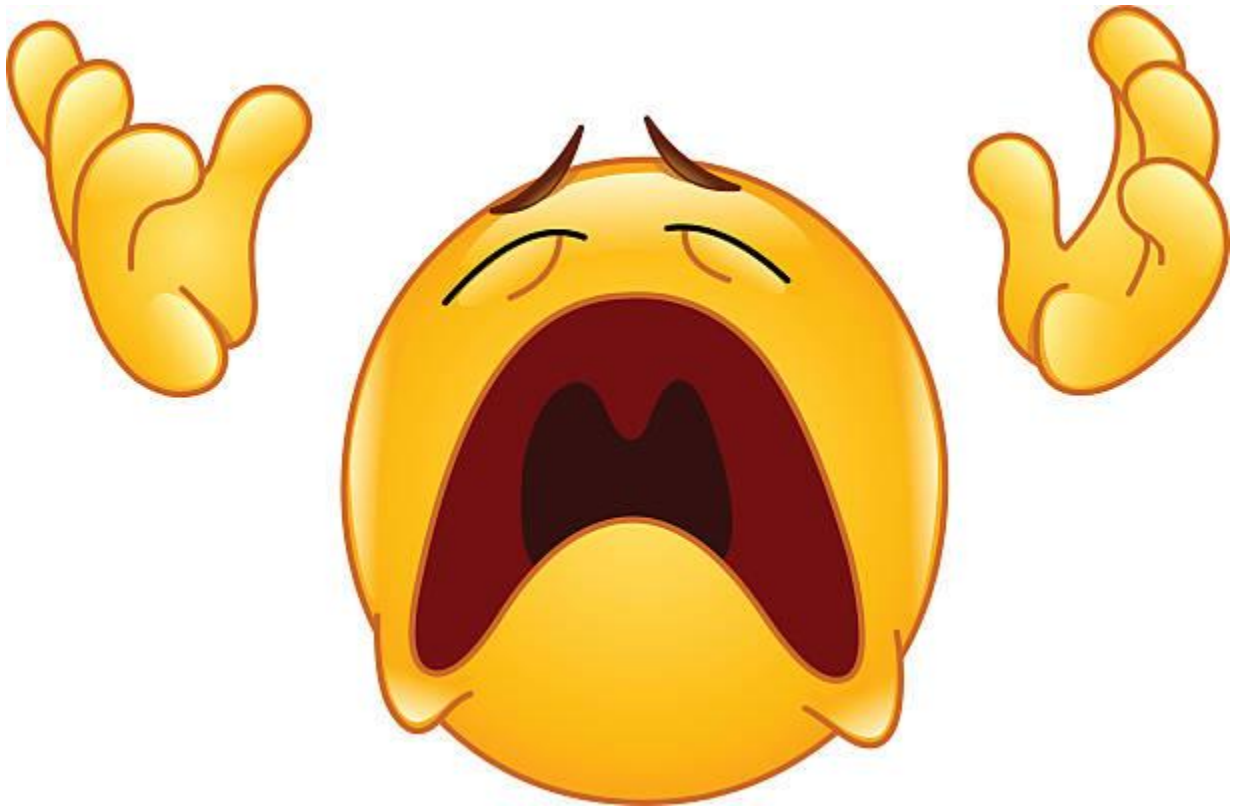
- Siden SWR er konstant kan vi legge på sirkler for å vise hva SWR er




+j1
+j0.5
+j2
+j0.2
+j5
0.0
0.2
0.5
1
2
5
30
+j30
∞
-j30
-j0.2
-j5
-j0.5
-j2
-j1

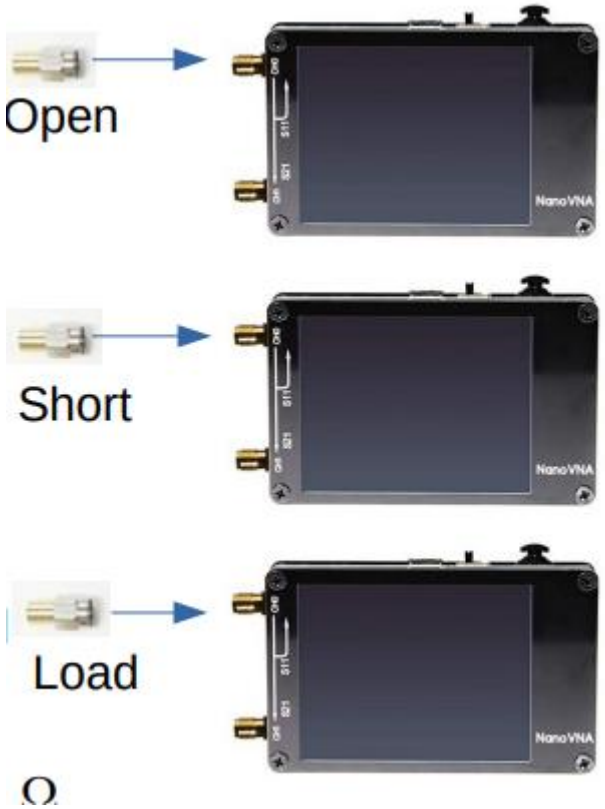
Antennemåling

- Enkelt! Antenner er en port
- Men vi må kalibrere først…



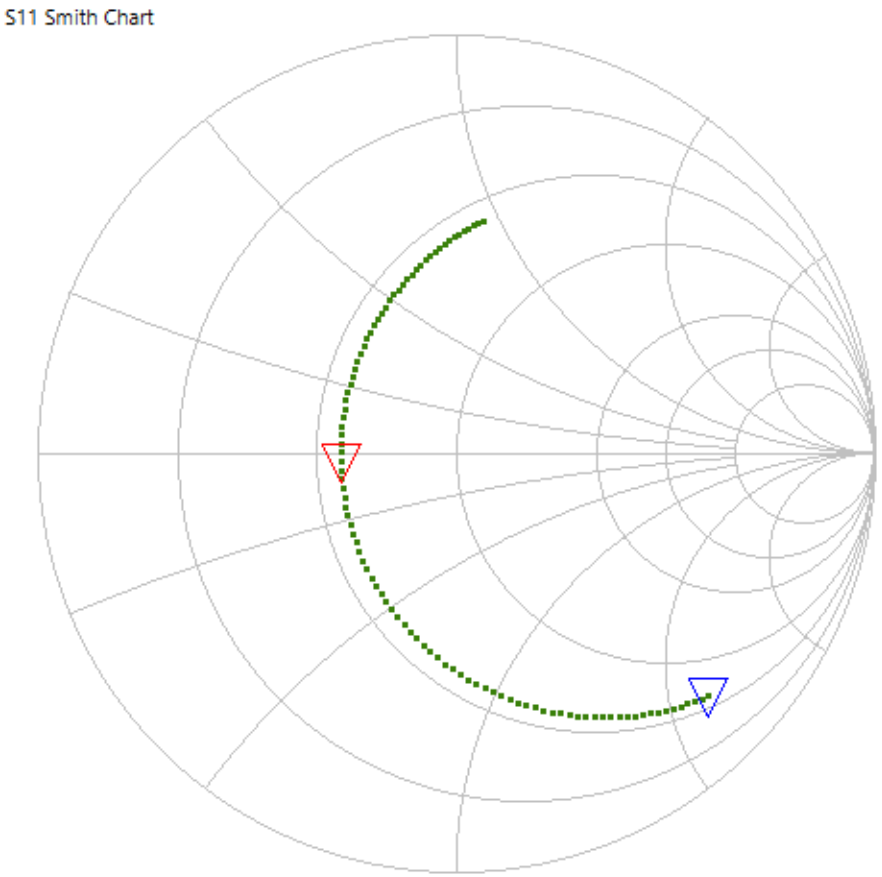
Hva er kalibrering?

- Forteller VNA hva som er åpen og kortsluttet.
- Kompenserer for feil i instrumentet
- Kan kompensere for ekstra coax
- SOLT – Short Open Load Transmission
- Frekvensavhengig

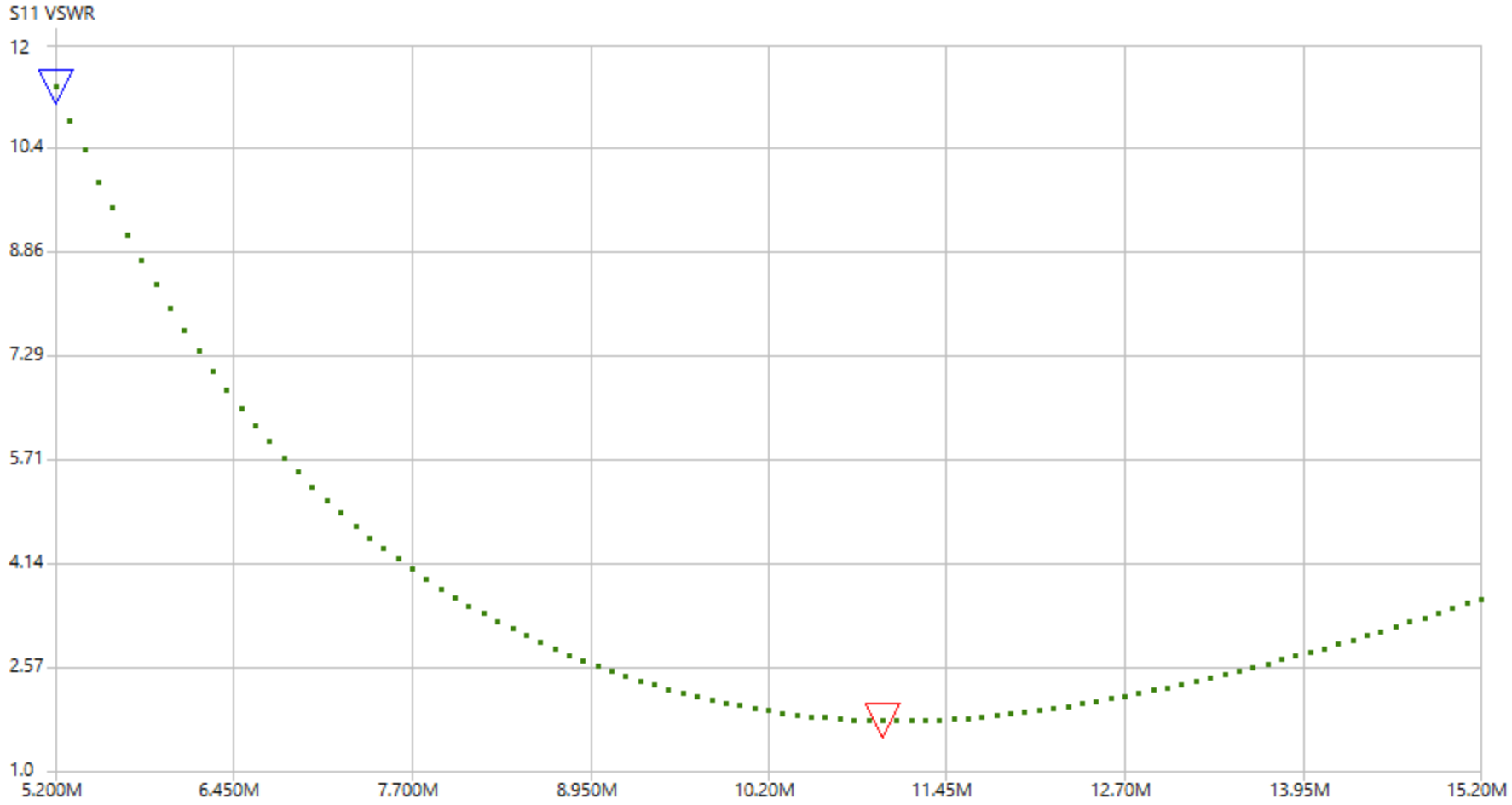


Da kan jeg måle antennen?

- Så lenge du ikke endrer frekvens ja
- Bruk markører til å vise frekvens



Eller gjør ting lett, få grafen rett i SWR

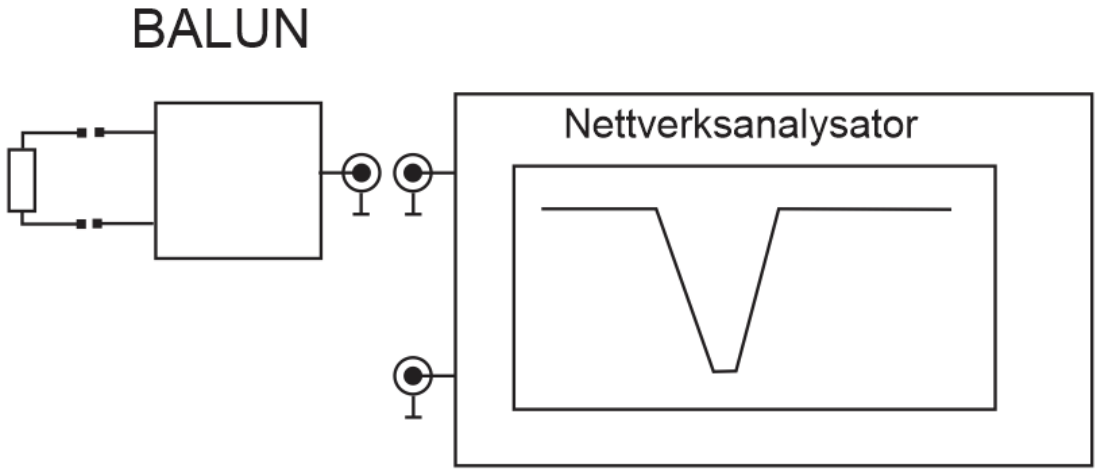


Er det alt vi kan? En oppskrytt antenneanalysator?

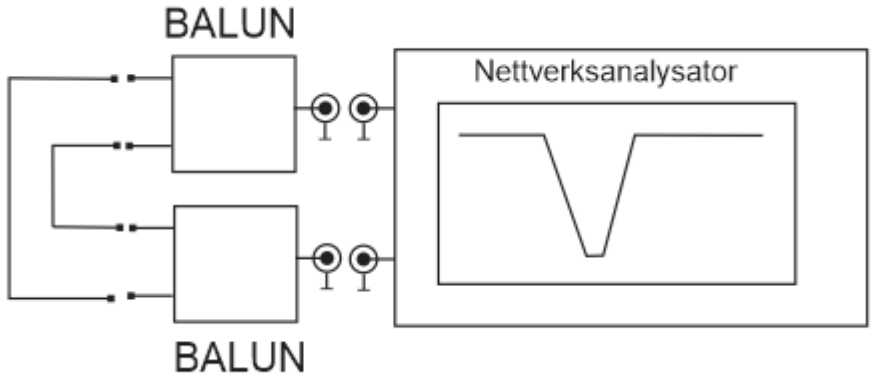
- Alt som har en eller 2 porter kan måles!
- Baluner
- Filtere
- Forsterkere
- Antenneswitcher
- Jordimpedans

Baluner

- Sett inn Motstand
- Mål tilpasning

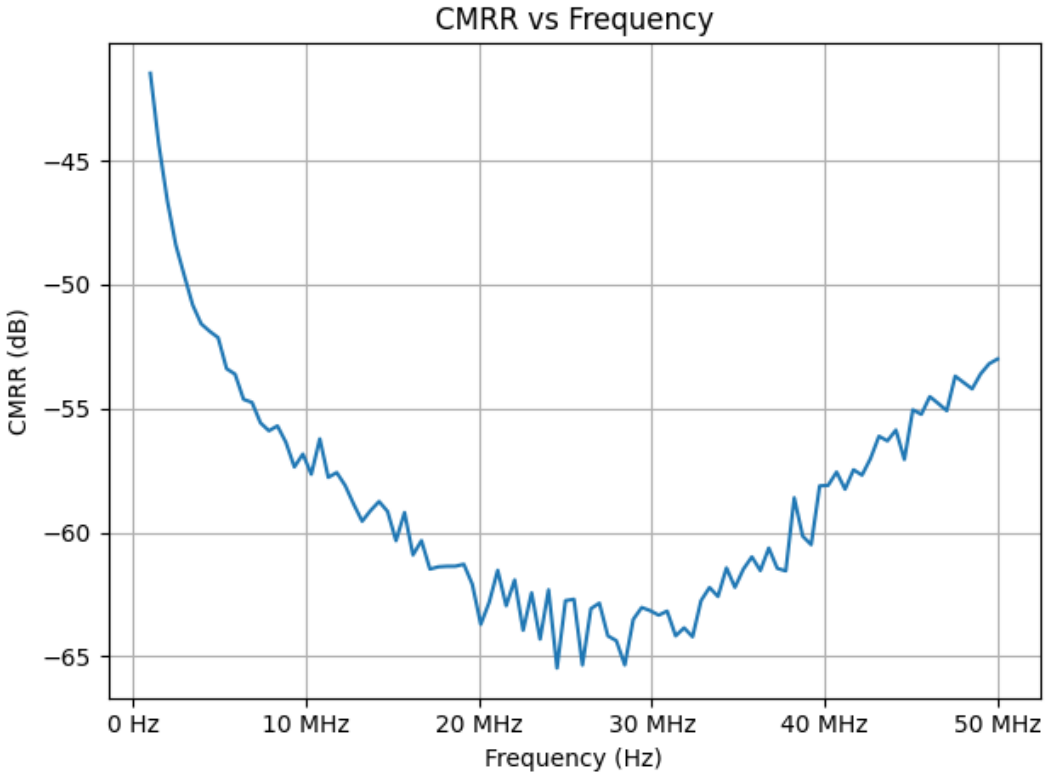


- 2 Like kan gi tapet
  - Mål tapet (S21) og del på 2



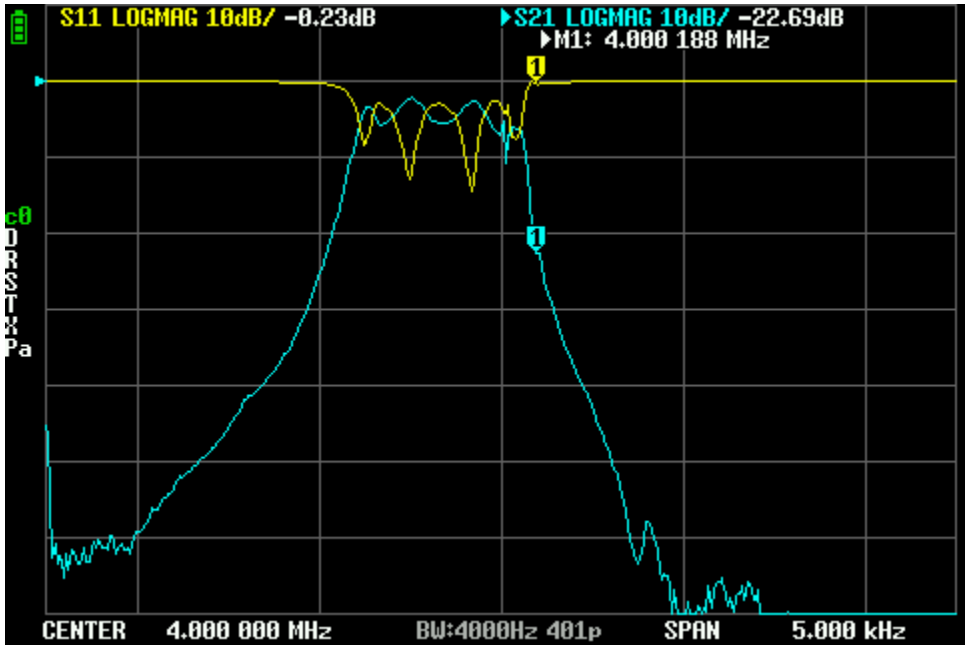
Common mode rejection

- Hvor mye demper en chocke common mode strømmer?
- Hvor fungerer den best?
  - Gjør 2 målinger
  - Lagre S-parameterene
  - Gjør litt matematikk
  - Resultatet ut som en graf



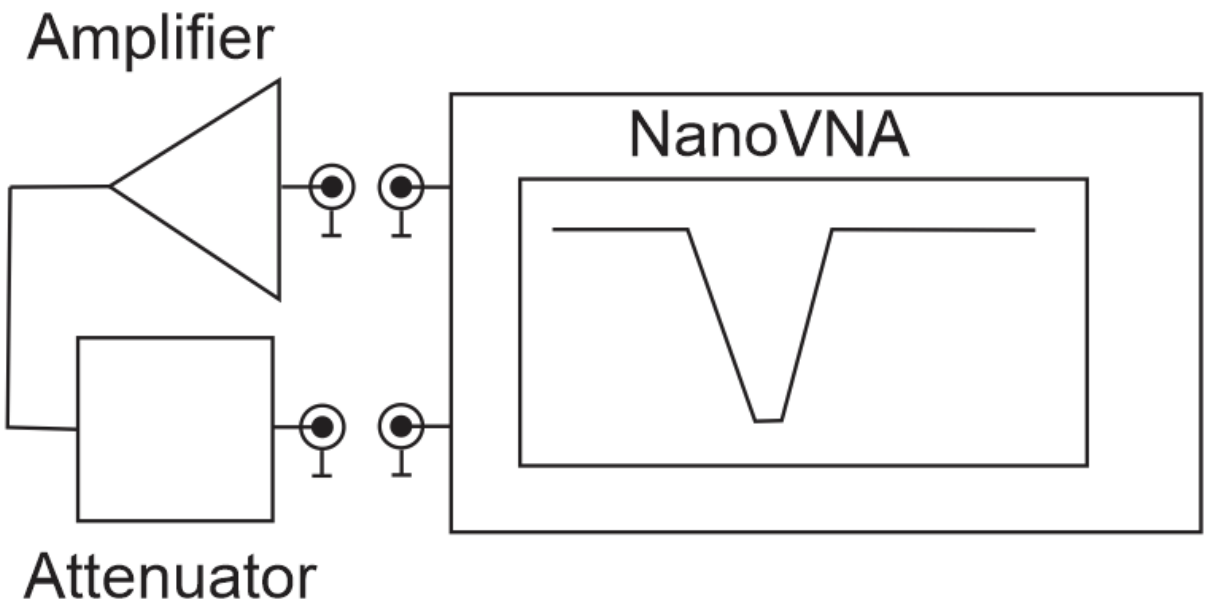
Filtere

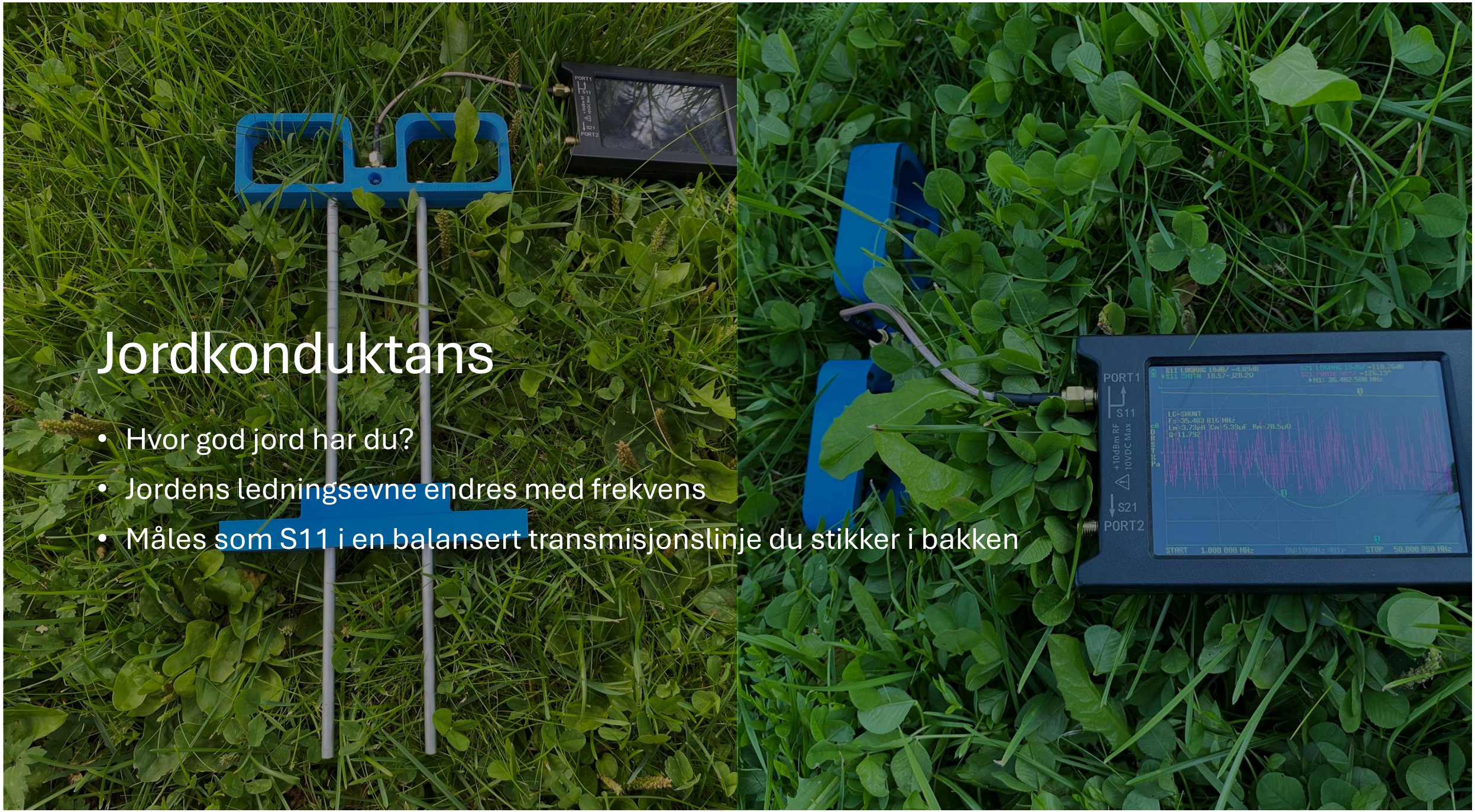
- Signal inn – Signal ut
- Impedanstilpasning
- Alle filtertyper kan måles
  - Notch er generelt vanskelig



Forsterkere

- Pass på inngangssignal
- Kalibrer med dempeledd på inngangen
- Fremover gir S11 og S21
  - Inngangsimpedans
  - Gain
- «Bakover» gir S22 og S12
  - Utgangsimpedans
  - Isolasjon
- Lagre filer og bruk software

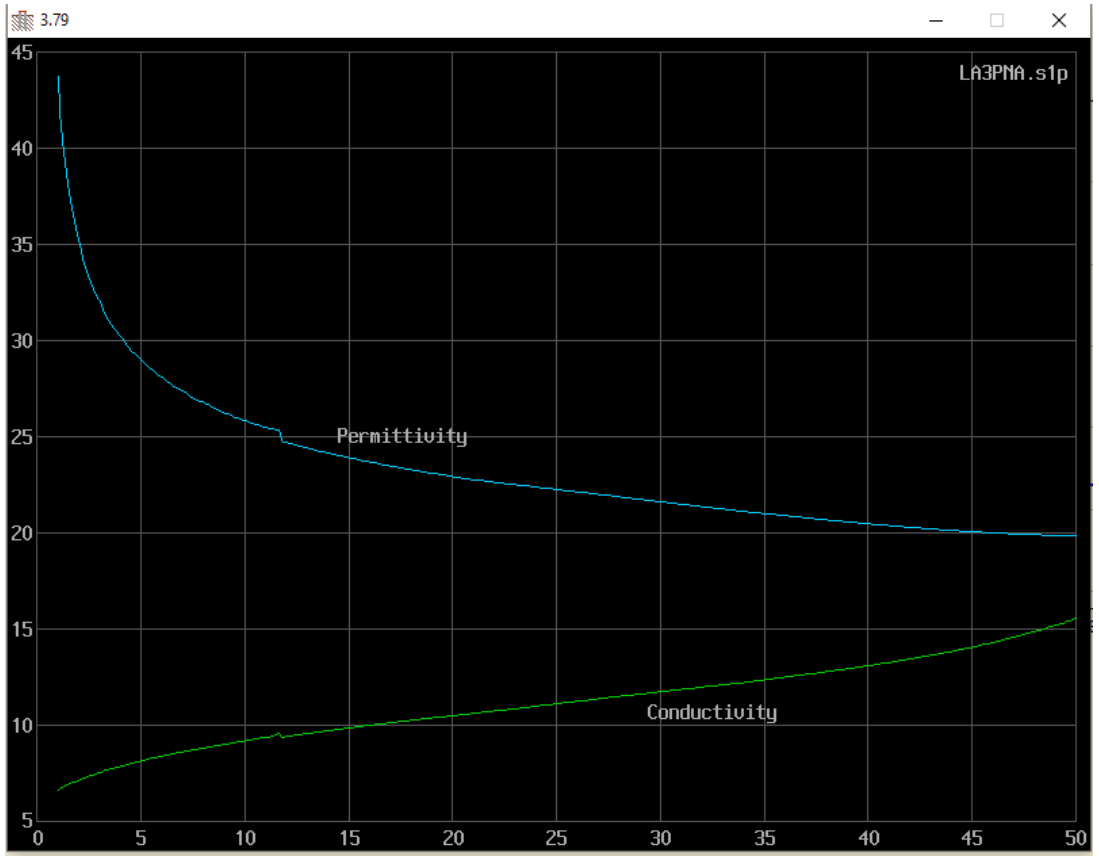


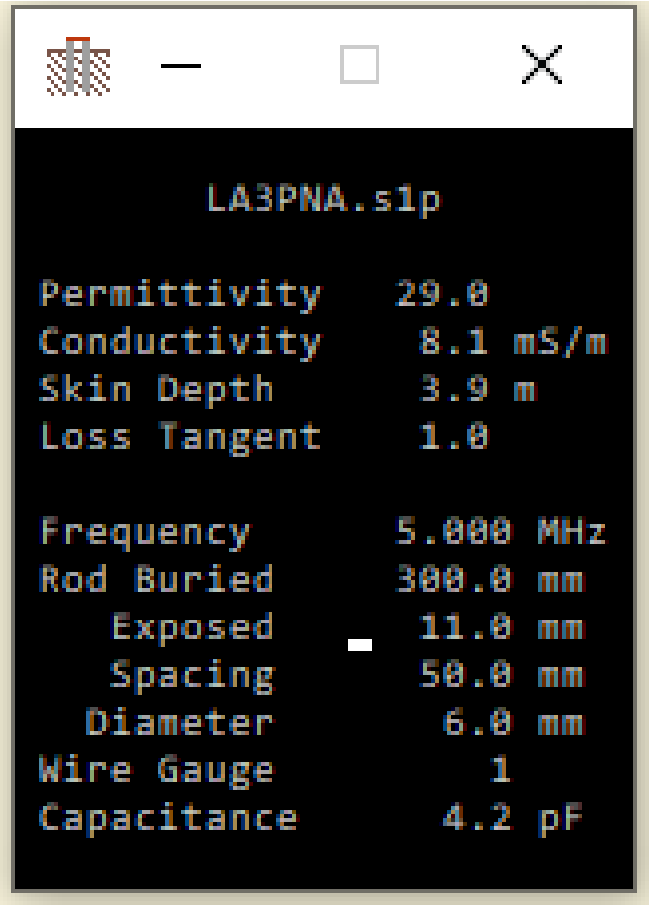


Jordkonduktans

- Hvor god jord har du?
- Jordens ledningsevne endres med frekvens
- Måles som S11 i en balansert transmisjonslinje du stikker i bakken

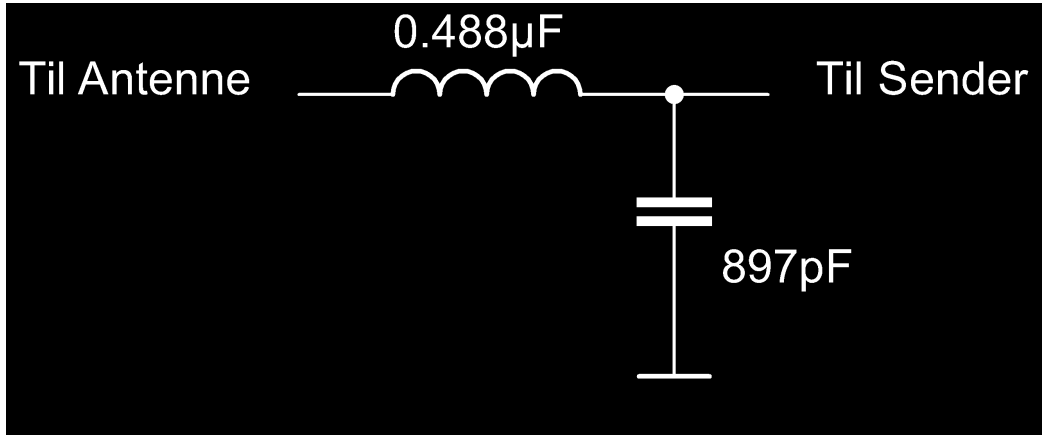
Jordkonduktans

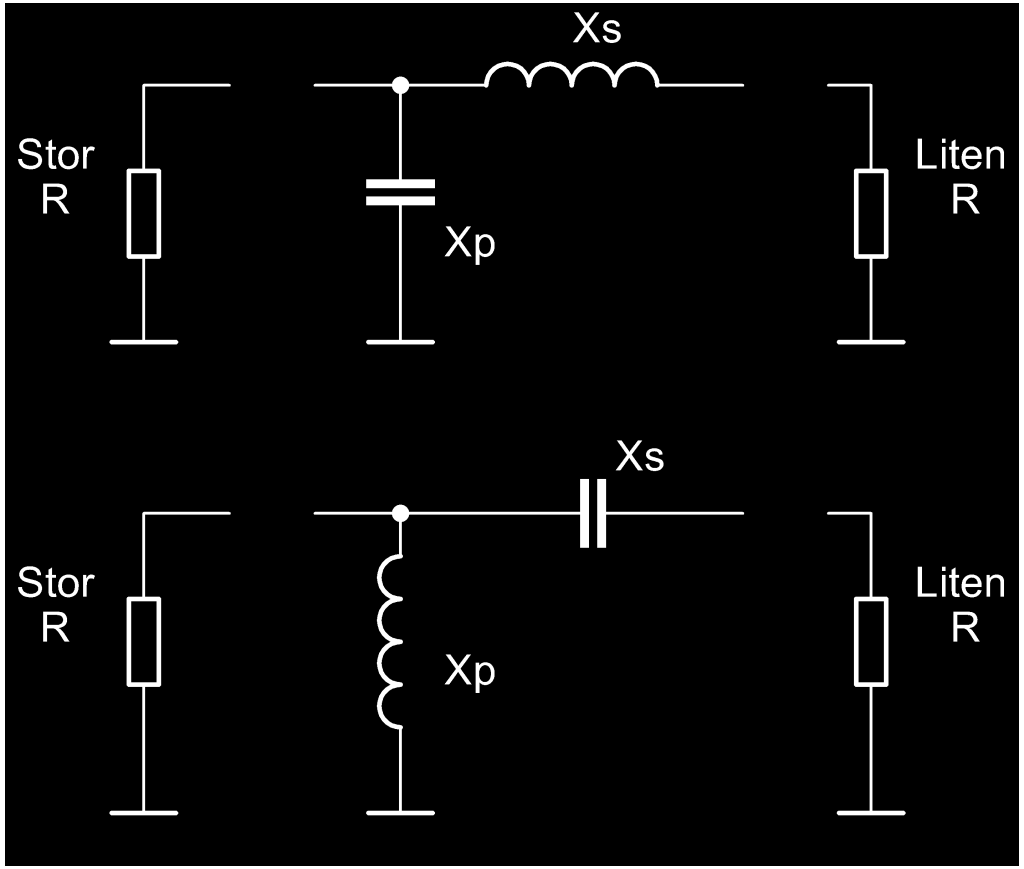




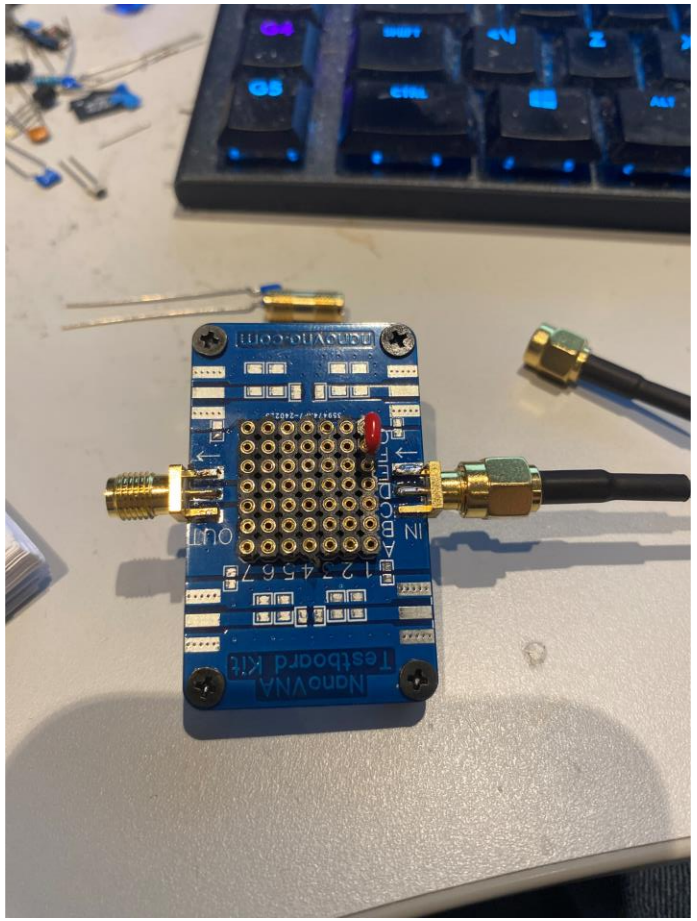
Eksperimentering?

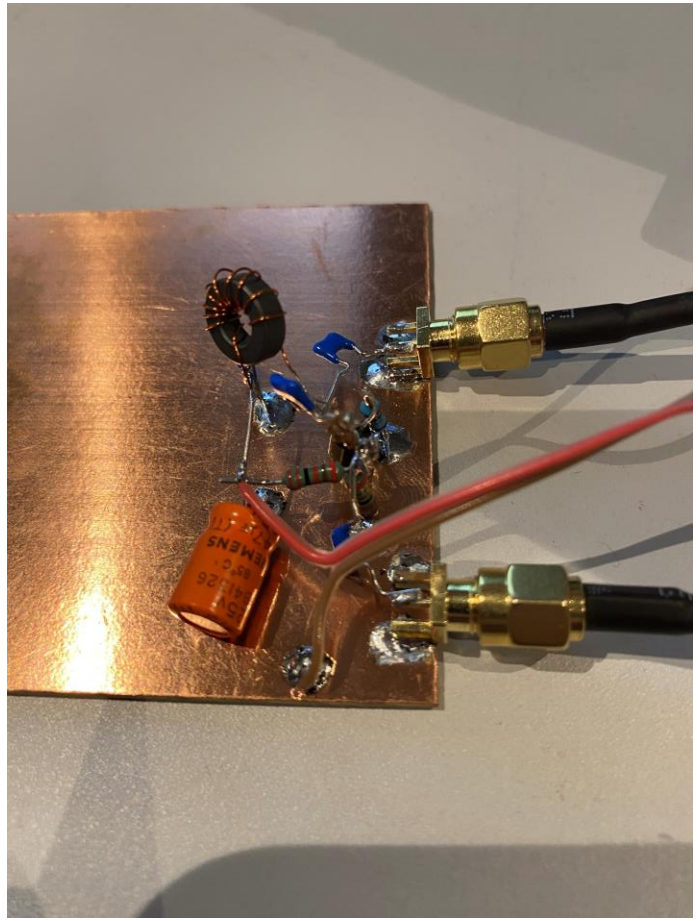
- Finne antenneimpedansen og tilpasse til coaxen ved antennen



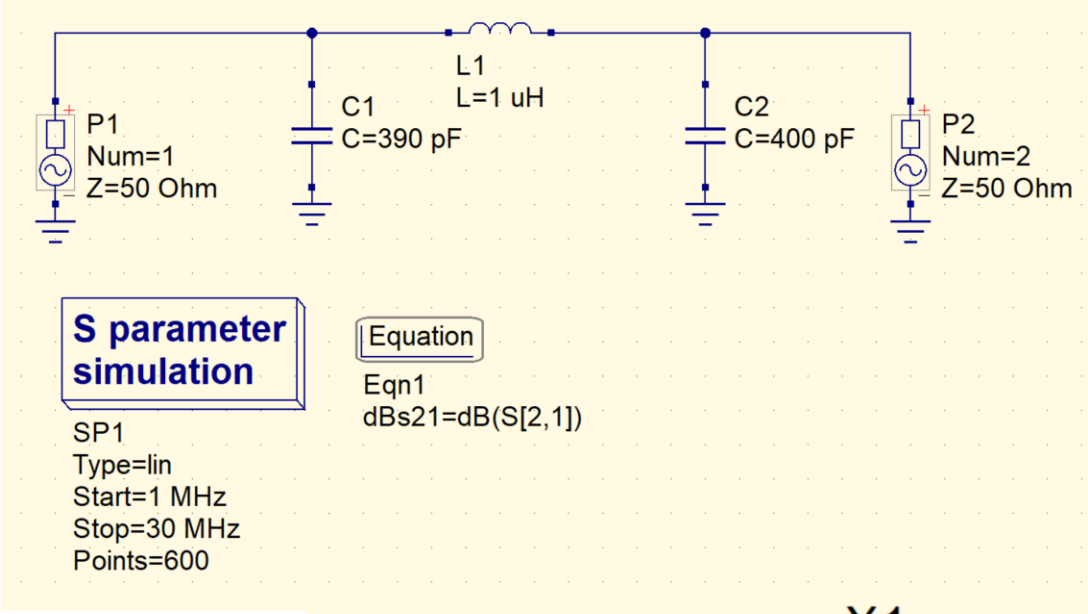


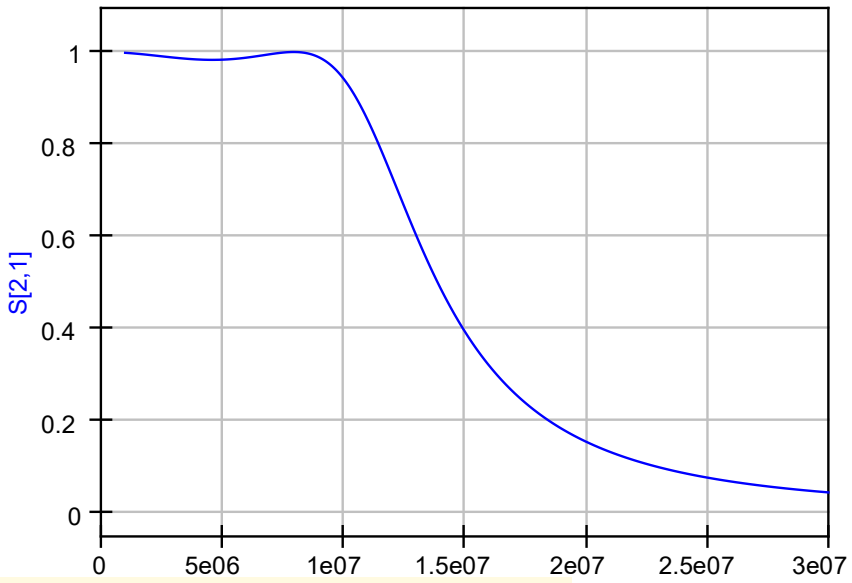
Eksperimentering!

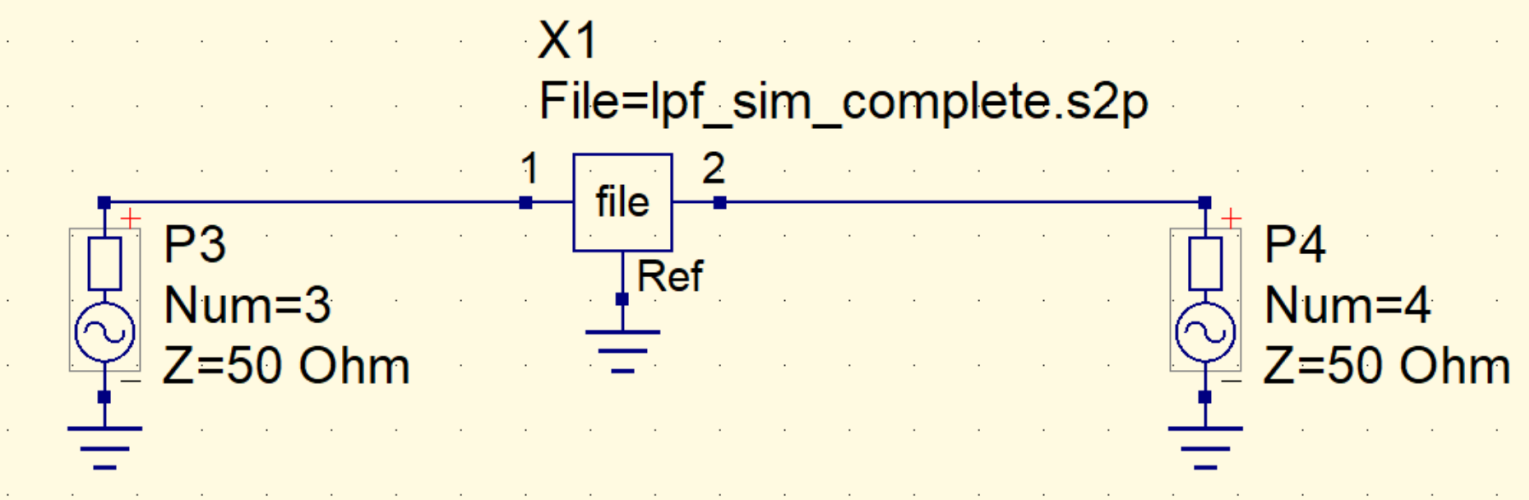


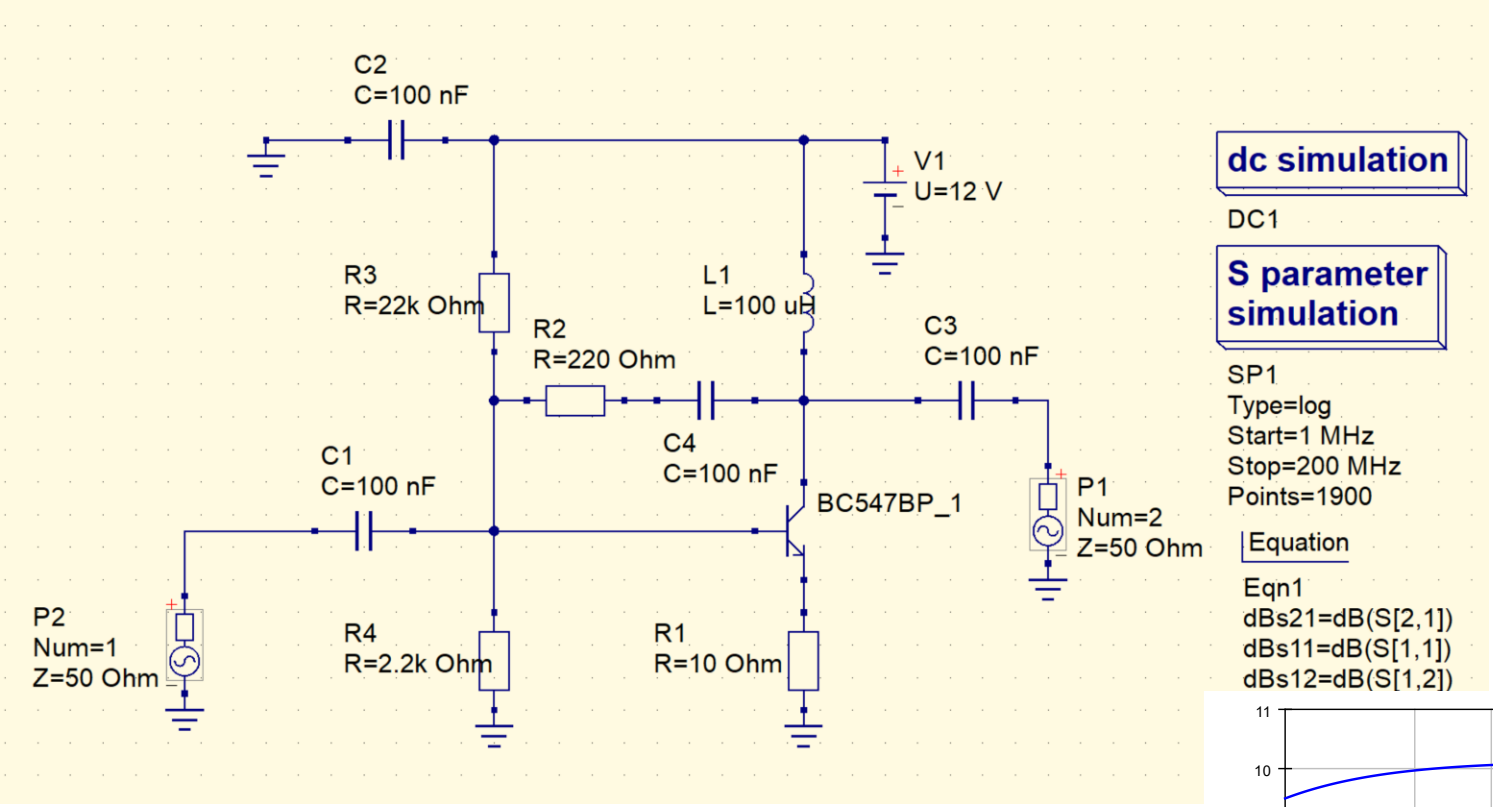


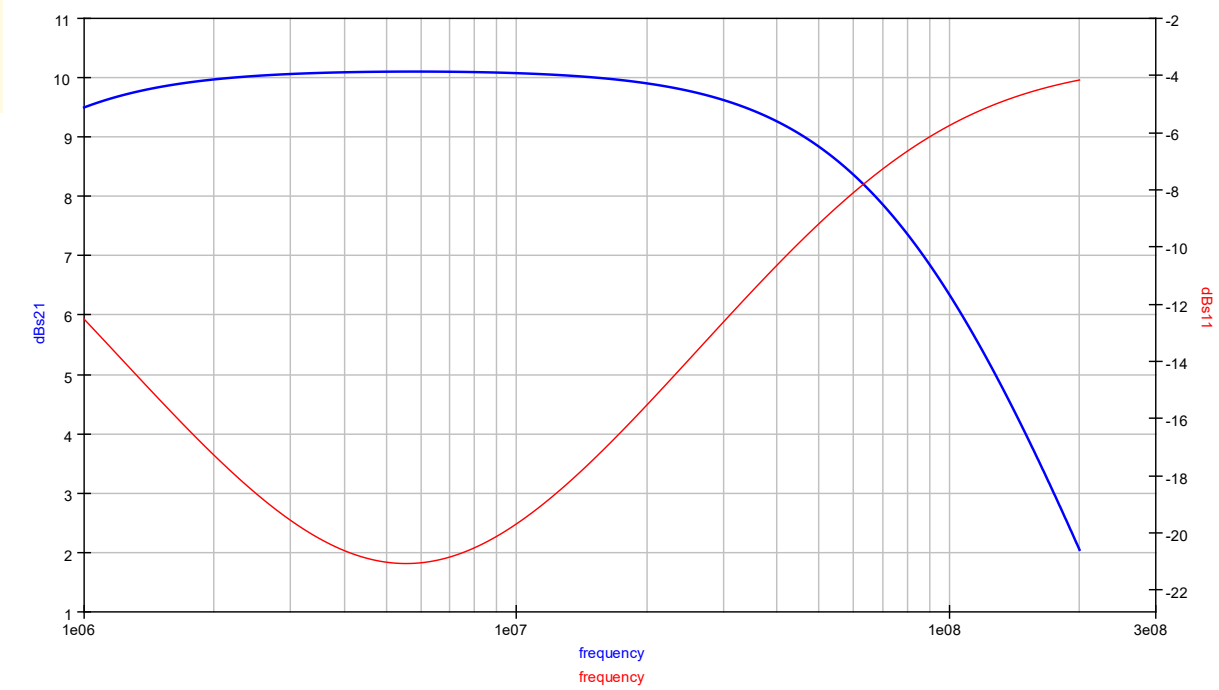
QUCS – Quite Universal Circuit Simulator



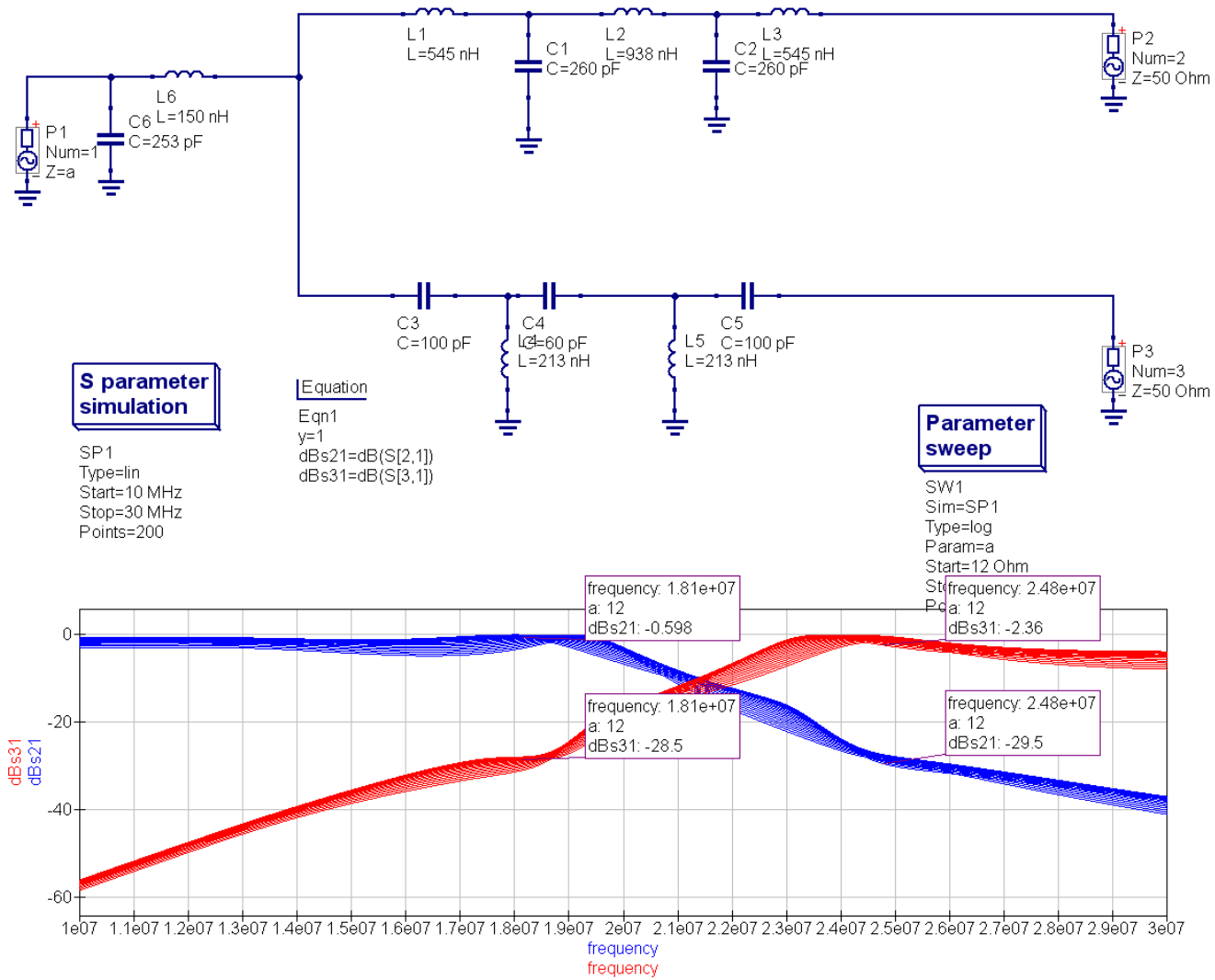





C2
C=100 nF
V1
U=12 V
R3
R=22k Ohm
L1
L=100 uH
R2
R=220 Ohm
C3
C=100 nF
C4
C=100 nF
C1
C=100 nF
BC547BP_1
P1
Num=2
Z=50 Ohm
P2
Num=1
Z=50 Ohm
R4
R=2.2k Ohm
R1
R=10 Ohm
dc simulation
DC1
S parameter simulation
SP1
Type=log
Start=1 MHz
Stop=200 MHz
Points=1900
Equation
Eqn1
dBs21=dB(S[2,1])
dBs11=dB(S[1,1])
dBs12=dB(S[1,2])


dBs21
dBs11
frequency
frequency
1e06
1e07
1e08
3e08

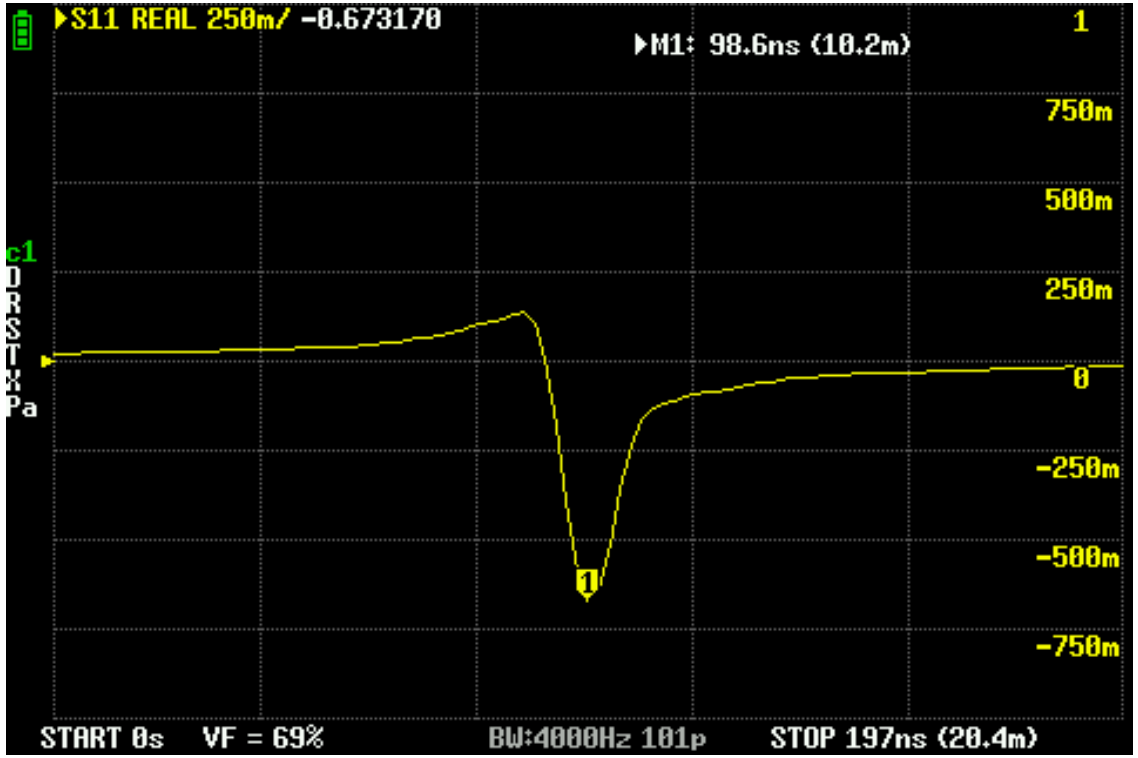
Diplexer 17m og 12m



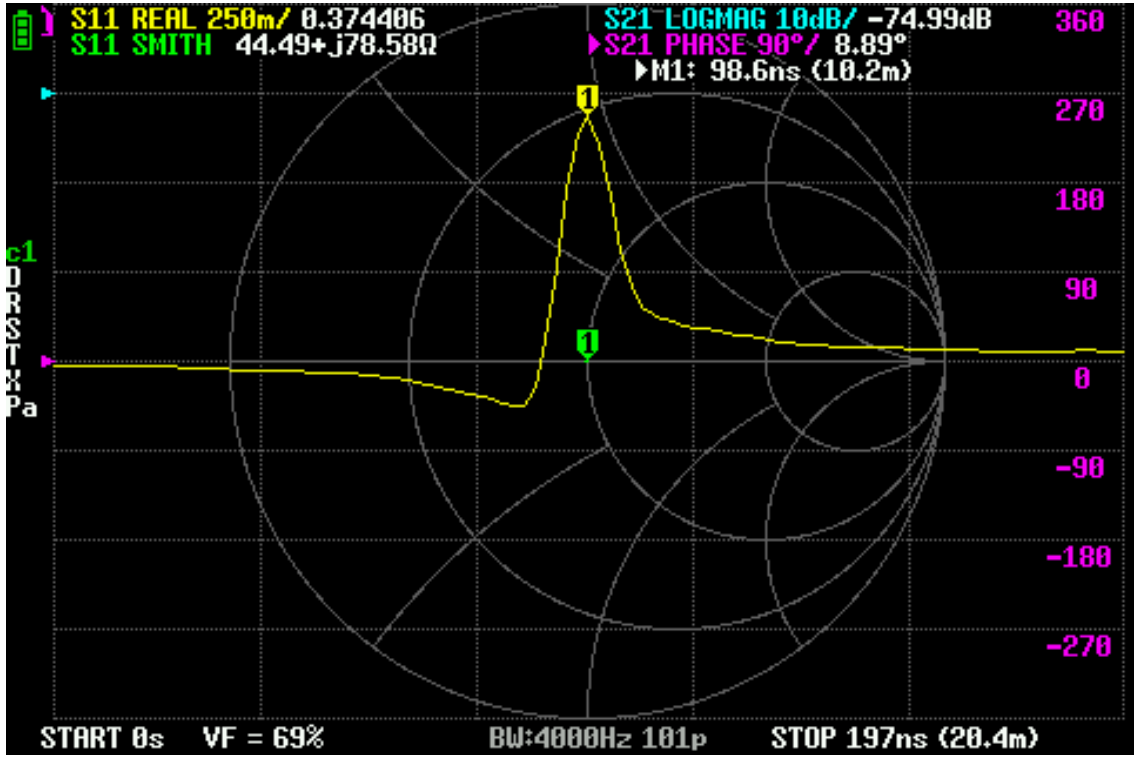
TDR - Tidsdomenereflektometri

- Finne avstand til feil

Kortsluttet



Åpen

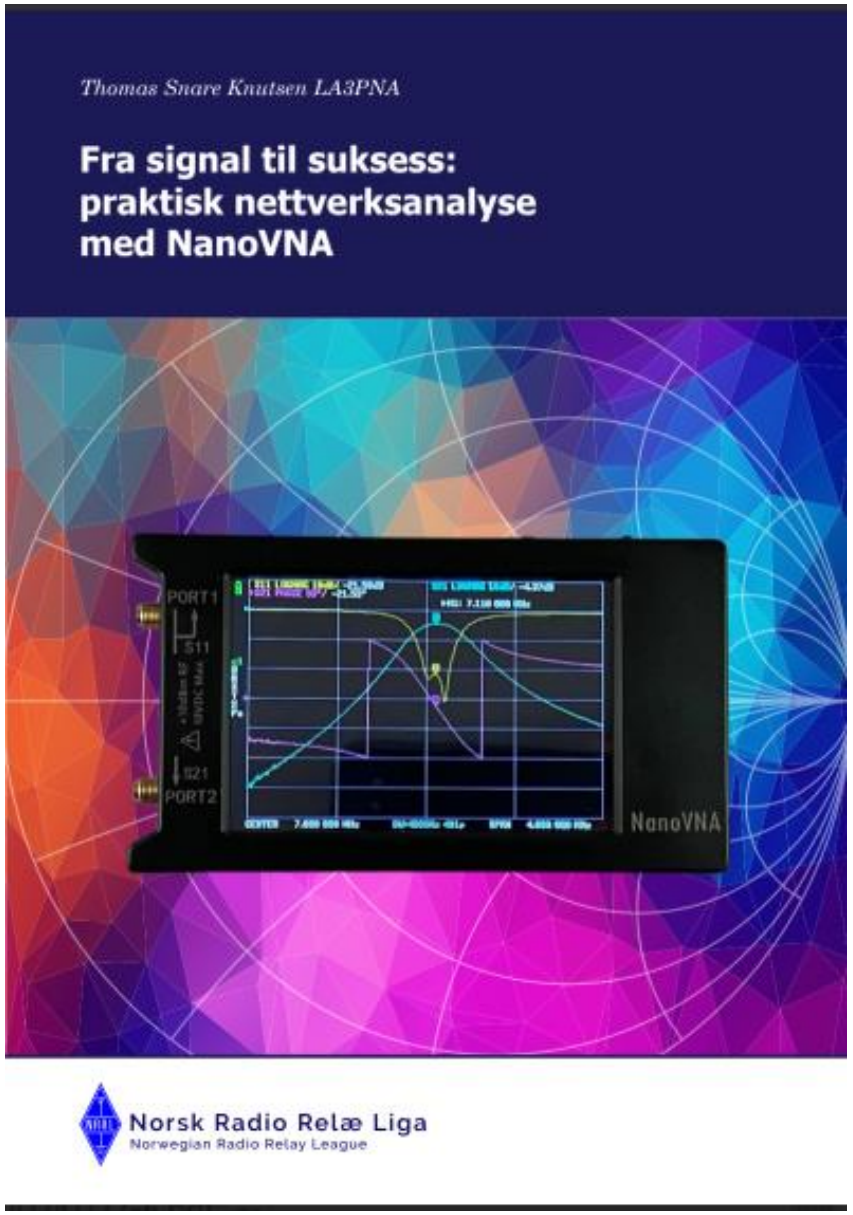


Trenger jeg en VNA?

- For prisen (runt 1000kr?)
- Ja definitivt! Den hører hjemme i enhver overmøblert shack

- NanoVNA står seg greit mot større dyrere instrumenter
  - 1000kr NanoVNA 1GHz
  - 800K R&S 26GHz
  - Dersom vi deler 800k på 26 burde NanoVNA kostet ca 30k, eller kanskje 15k?
  - Billig nok til at du ikke trenger å være for redd for å ødelegge den
  - Kjøp fra butikkene på hjemmesiden, ikke aliexpress og temu!

Spørsmål?


Thomas Snare Knutsen LA3PNA
Fra signal til suksess: praktisk nettverksanalyse med NanoVNA
PORT1
S11
S21
PORT2
NanoVNA
Norsk Radio Relæ Liga
Norwegian Radio Relay League