Real-time Adaptation to Antenna Impedance Mismatch for CDMA Transceivers

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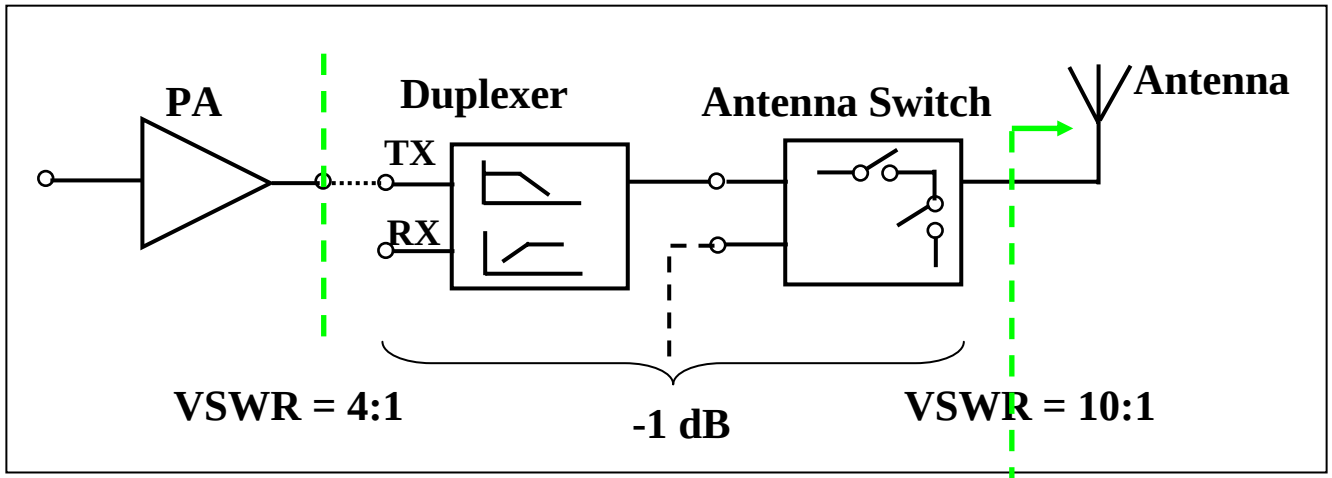
UCSD

Outline

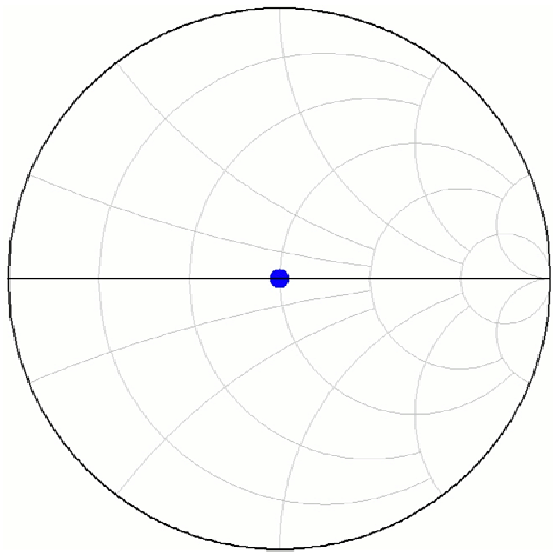
- Introduction
- Design of Tunable Matching Network
- Antenna Load Impedance Measurement Using Sectioned Transmission Line
- Closed-loop Measurement Results
- Conclusions

Introduction

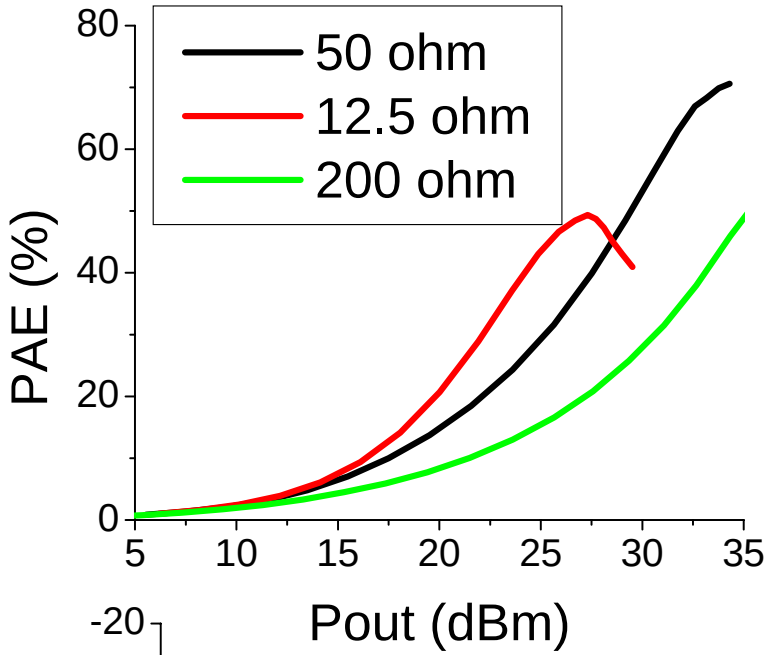


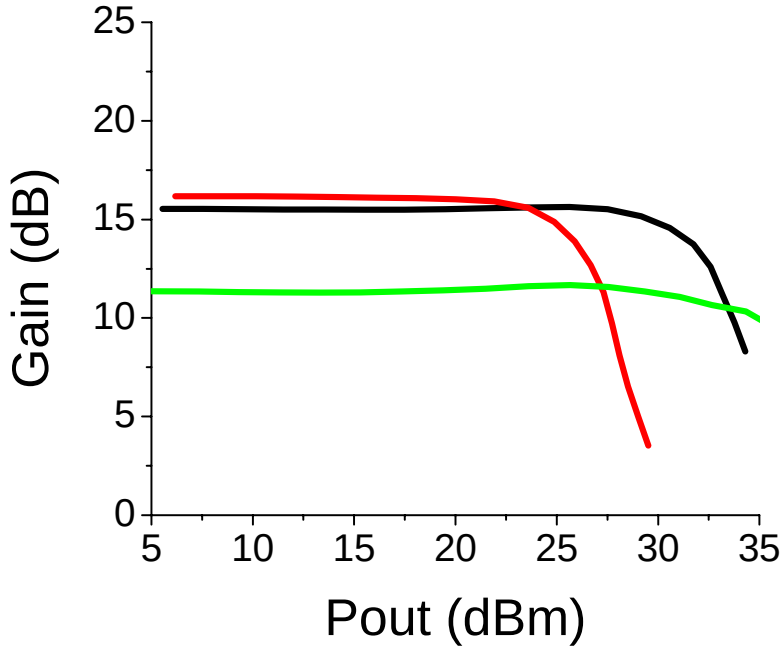
- VSWR at antenna ref. plane can vary up to 10:1 with any phase.

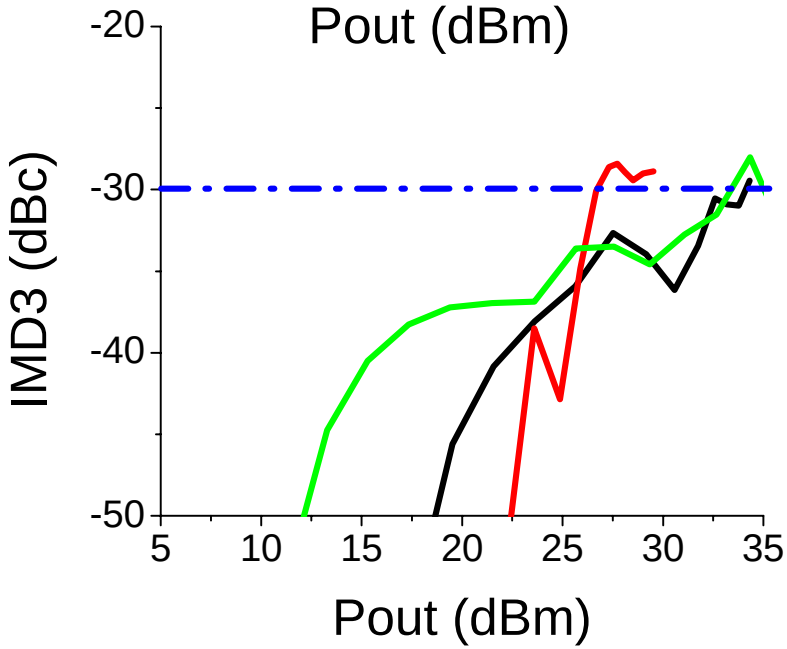
- It is a challenge to maintain optimum operation of the transmitter with such a wide range of impedance.



Performance of PA with Different Load





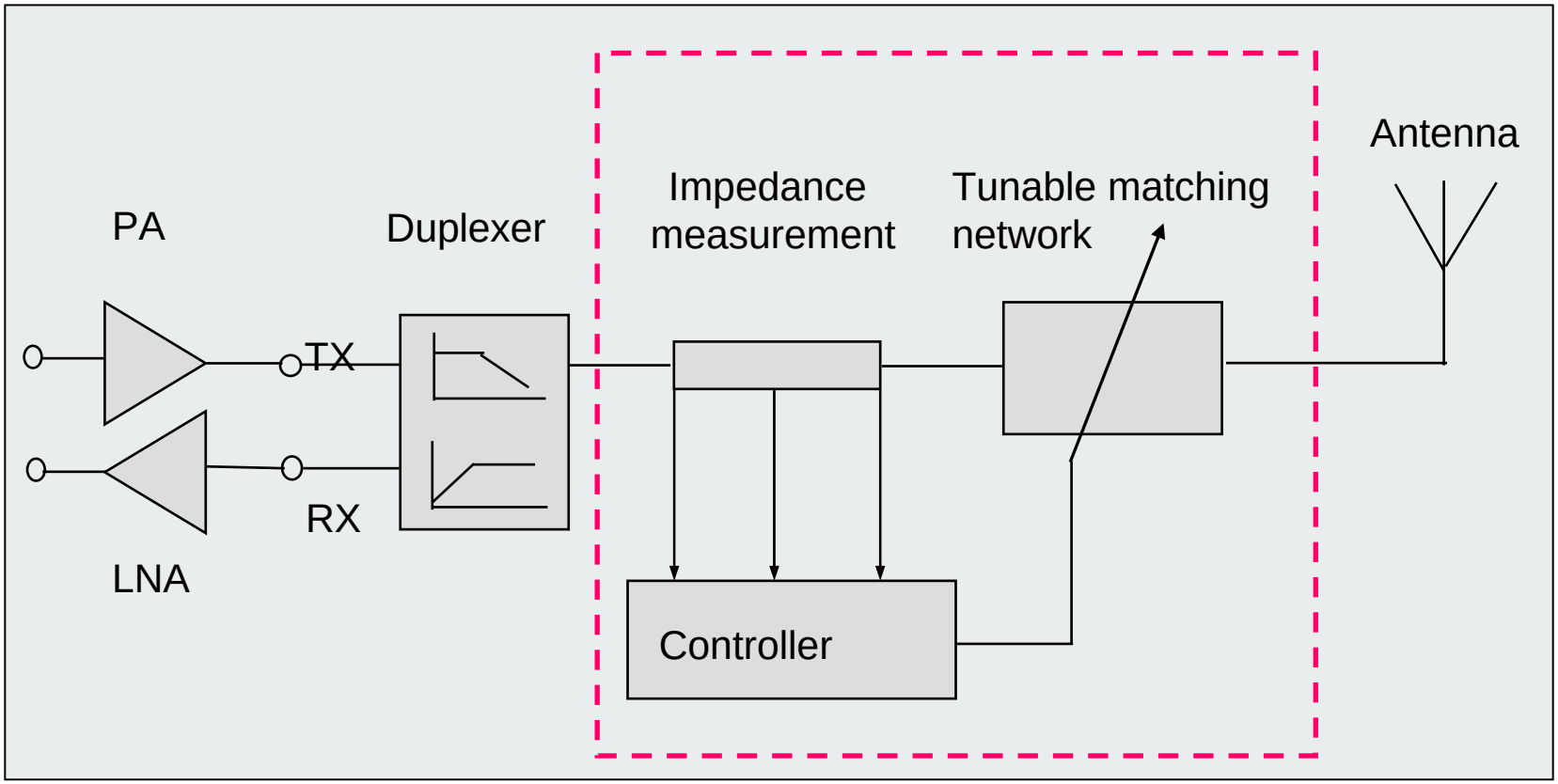


ADS simulation results for a class AB amplifier designed for 50 ohm

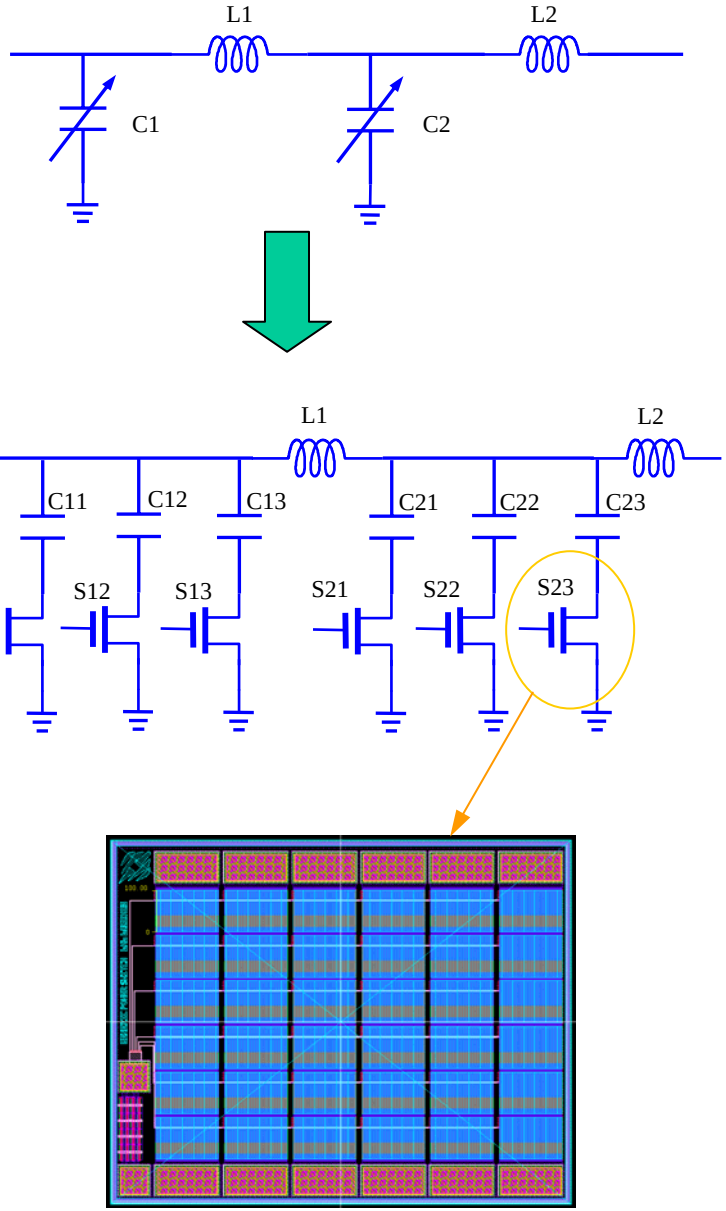
Mismatch Also Impacts:

- Stability: Possible oscillation of power amplifier thus damaging the amplifier
- Duplexer insertion loss

Adaptive Transmitter



Tunable Matching Network With Silicon-on-Sapphire Switches

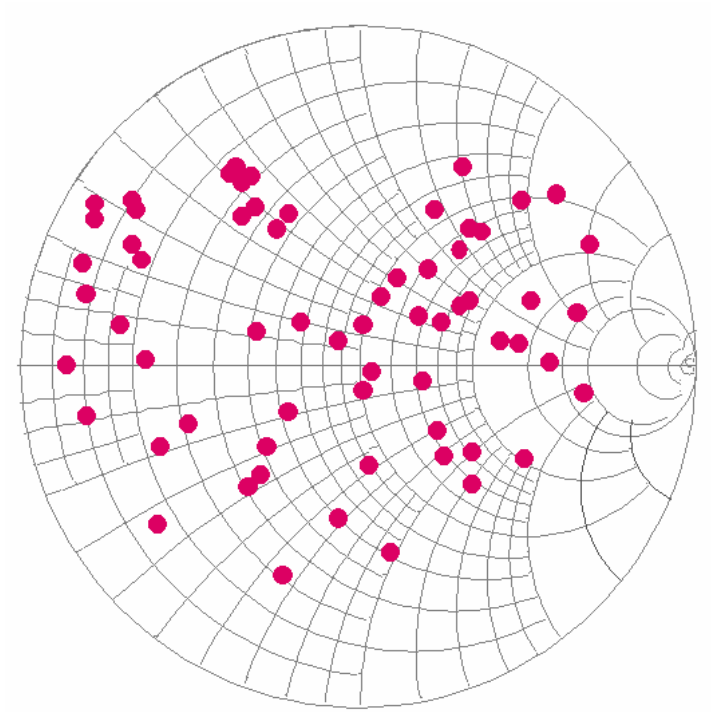


Compared to bulk CMOS, SOS has:

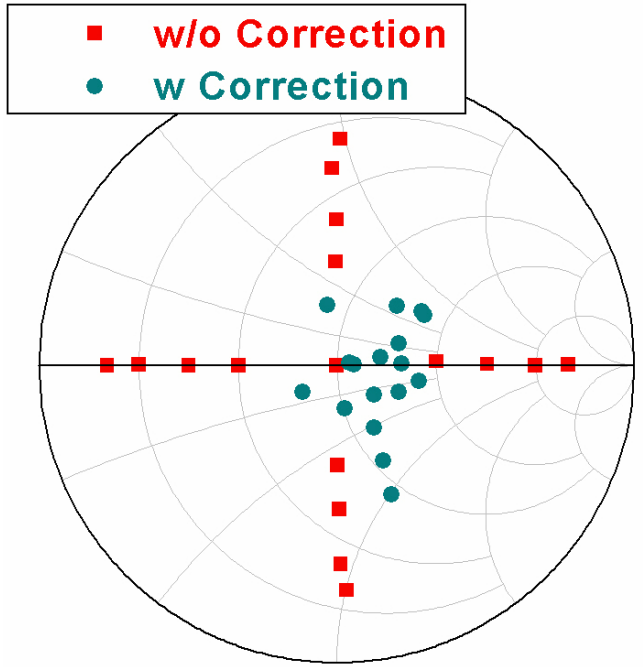
- **Reduced component-substrate parasitic capacitance**
- **Improved isolation between transistors**

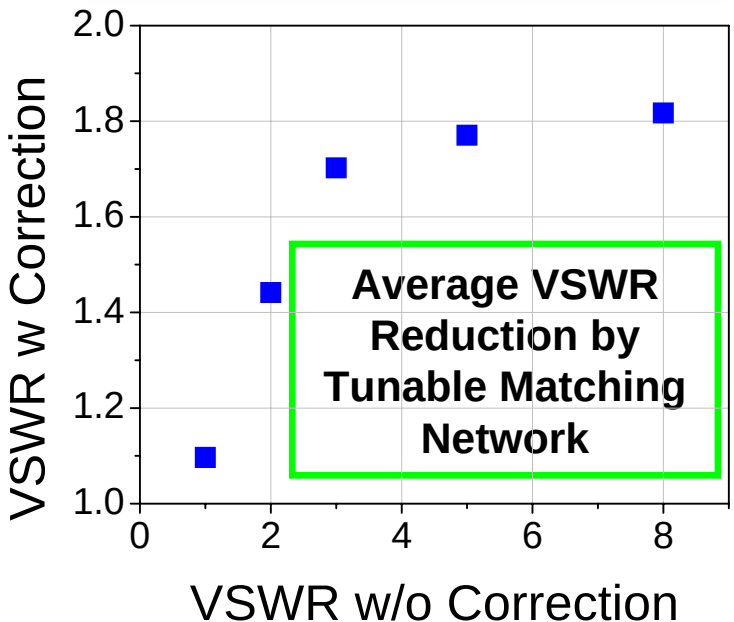
- Stack of 6×6 parallel available
- W/L = 6000um/0.5um per FET
- Ron and Coff scale linearly with stacking / adding parallel devices
- BVDSS (2 nA/um) = 2 V
- Recommend +/- 2 to 3 V bias
- Ron = 0.5 ohm (2.75 ohm-mm) @ 3 V
- Coff = 1.8 pF (300 fF/mm)
- Gate is ESD protected

Characteristics of Tunable Matching Network

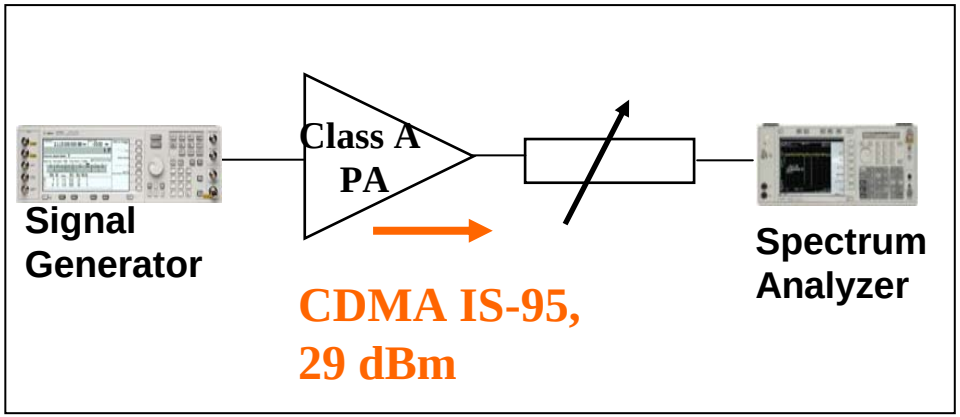


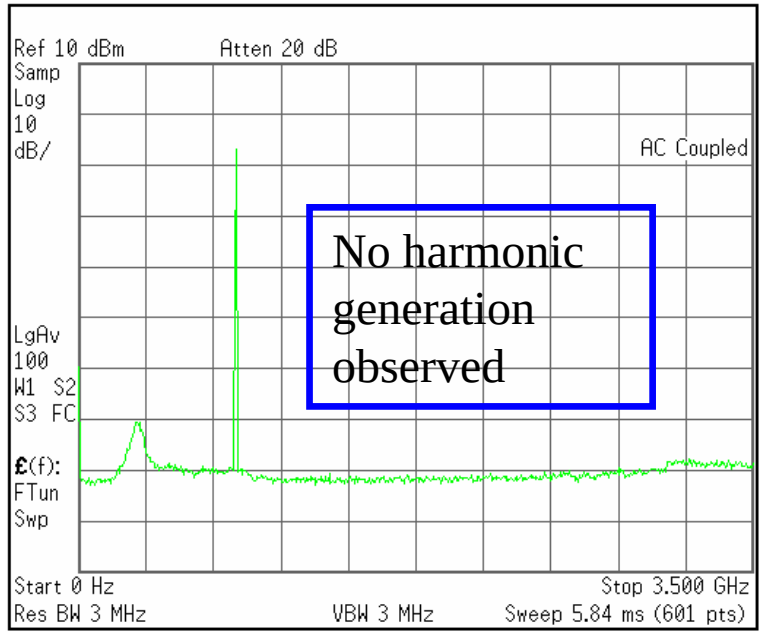
Available impedance of the tuner



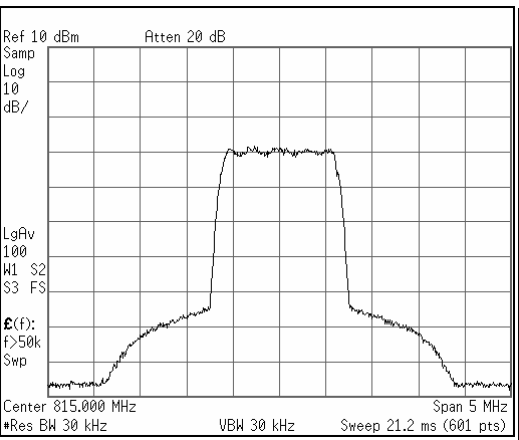


Linearity and Insertion Loss

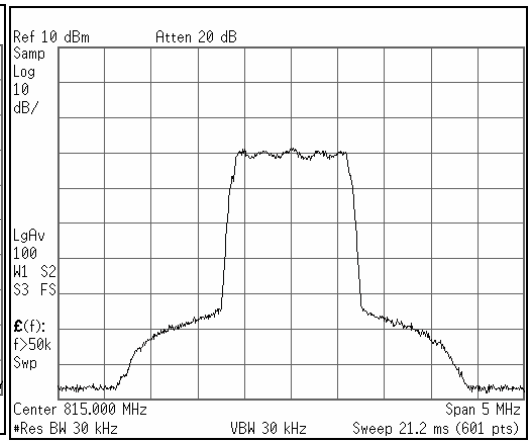




Without Tunable Matching Network



With Tunable Matching Network

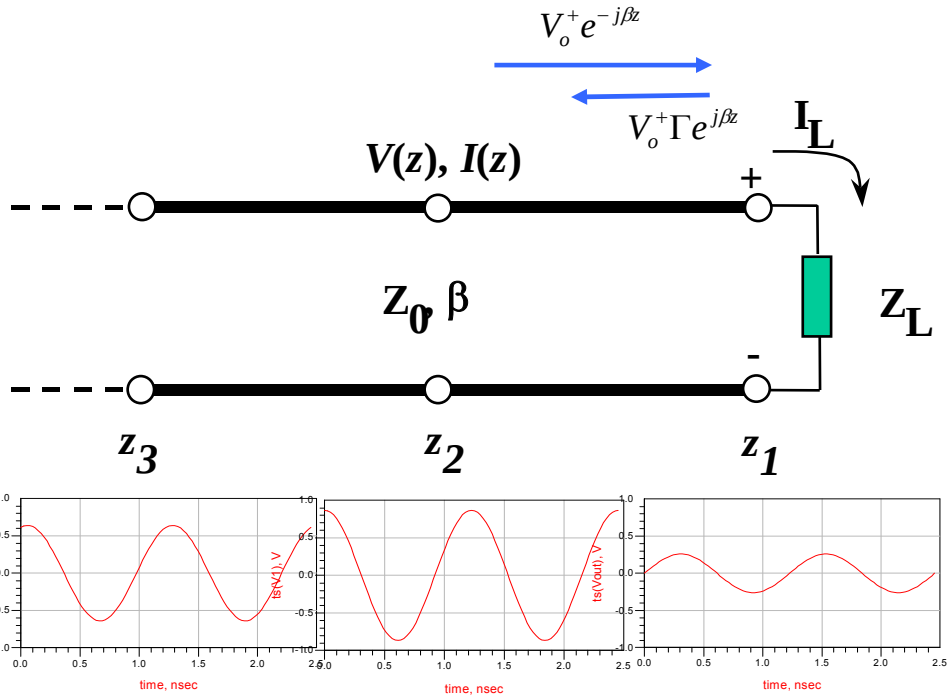


ACPR = -59.5 dBc **ACPR = -59.2 dBc**

(for the switch setting close to 50 Ω)

- **For switch setting close to 50 Ω, insertion loss ~ -0.36 dB. Could be reduced further if tuned to 50 ohm**
- **Maximum available gain varies for different switch settings. Average maximum available gain ~ -0.25 dB.**

Measurement of Load Impedance Using Transmission Line



$$V(z) = V_o^+ \left[e^{-j\beta z} + \Gamma e^{j\beta z} \right]$$

$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} \qquad \beta = w\sqrt{LC}$$

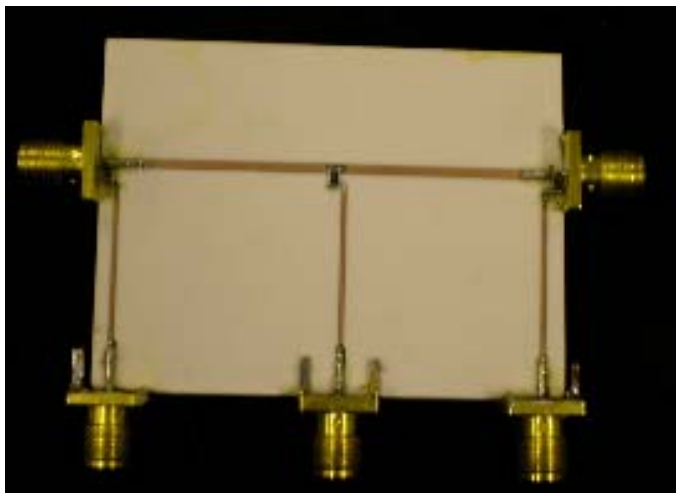
$$r = \frac{V_{z1}}{V_{z2}} = \frac{e^{-j\beta z_1} + \Gamma e^{j\beta z_1}}{e^{-j\beta z_2} + \Gamma e^{j\beta z_2}}$$

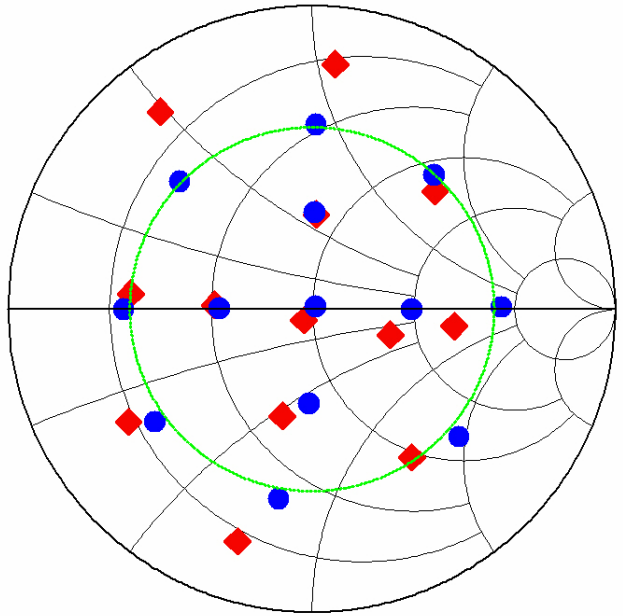
Z0 = 50 ohm, Z_L = 15 ohm,
90° Transmission Line

- **Measurement results depend on voltage ratios, not the voltages**
- **Independent of input power and the source impedance**

Measurement Setup

- **Fabricated on PCB board**
- **¼ λ transmission line**
- **815 MHz**
- **Single tone and CDMA IS-95**



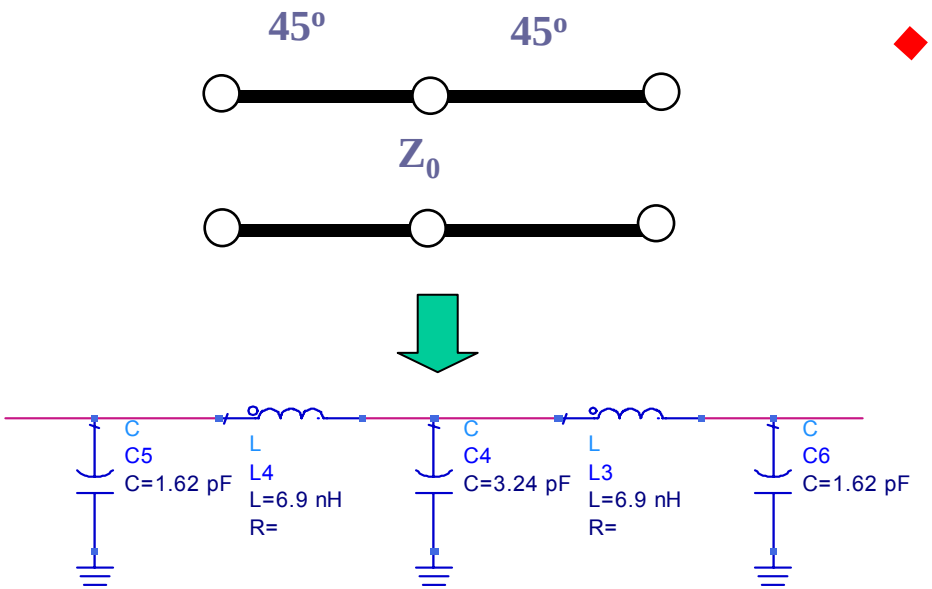


- **Measured by Network Analyzer**
- **Measured by Transmission Line**

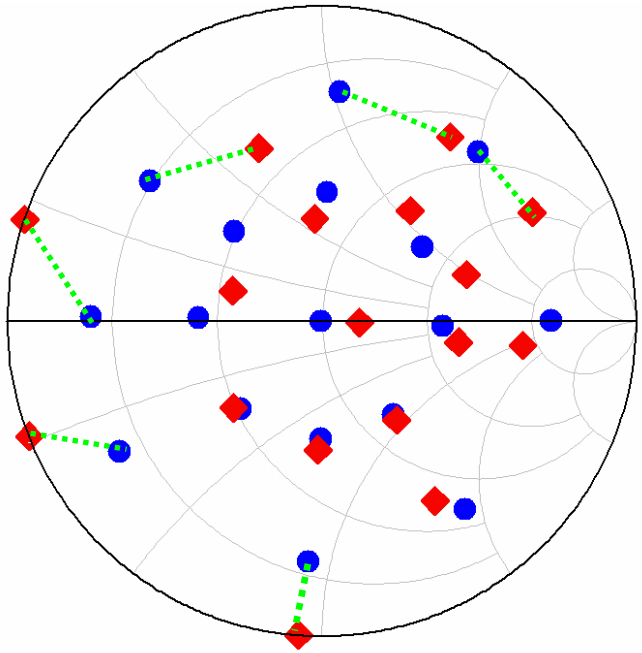
CDMA

Three input power levels (12, 14 and 16 dBm)

Load Impedance Measured by Artificial TL

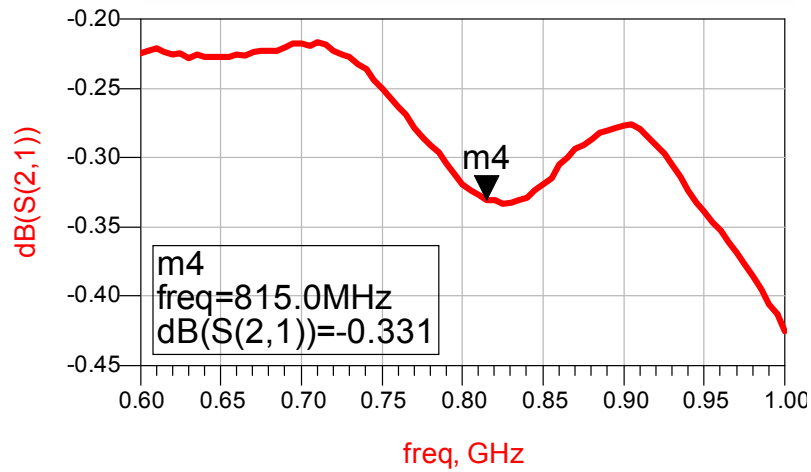


- Measured by Network Analyzer
- Measured by Transmission Line

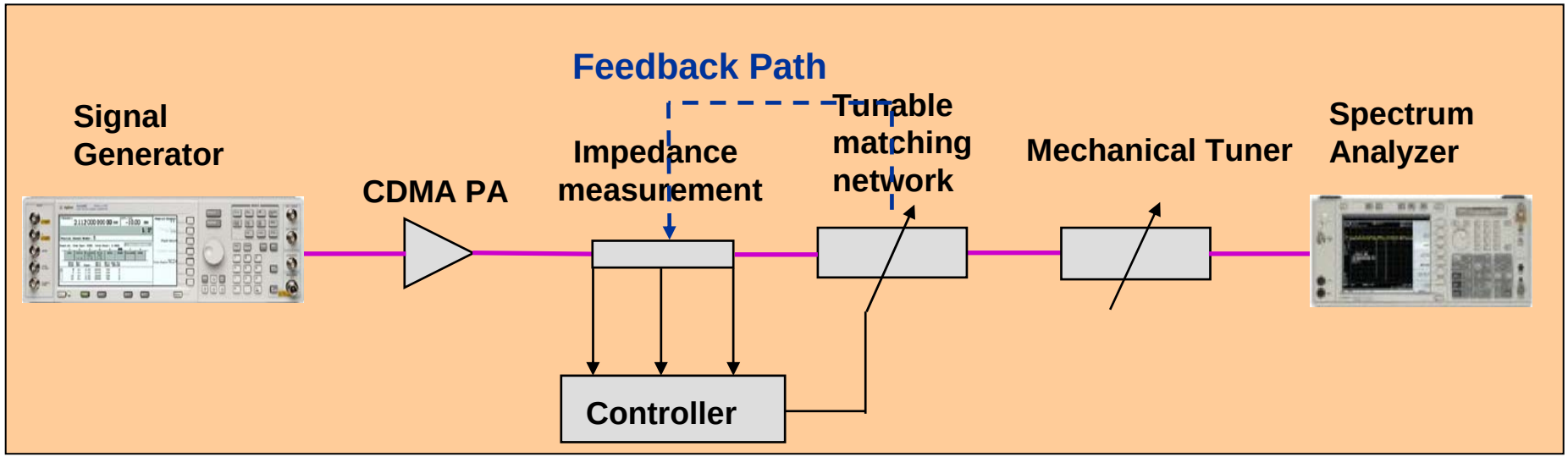


Coilcraft inductors (Q > 100)
CDMA IS-95

Part of the error was caused by the fact that the lumped elements do not have the same values as calculated for the artificial transmission line

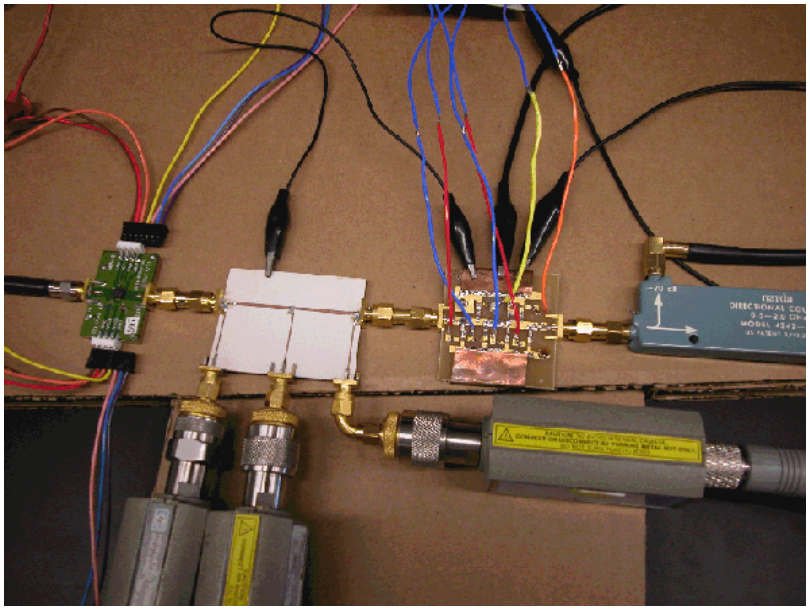


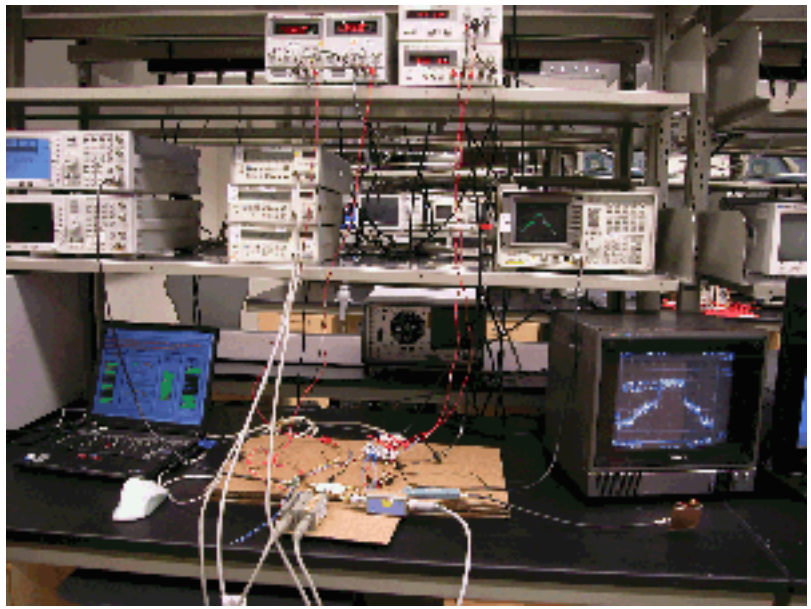
PA with Closed-loop Control



- Control logic: voltages ratios are tuned close to 1 by changing switch settings (load impedance close to 50 Ω)
- GPIB interface controlled by LabView
- Skyworks CDMA Handset PA CX77105 (GaAs HBT)
- IS-95, 824MHz, Fixed 0 dBm Pin (~ 28 dBm Pout for 50 Ω)

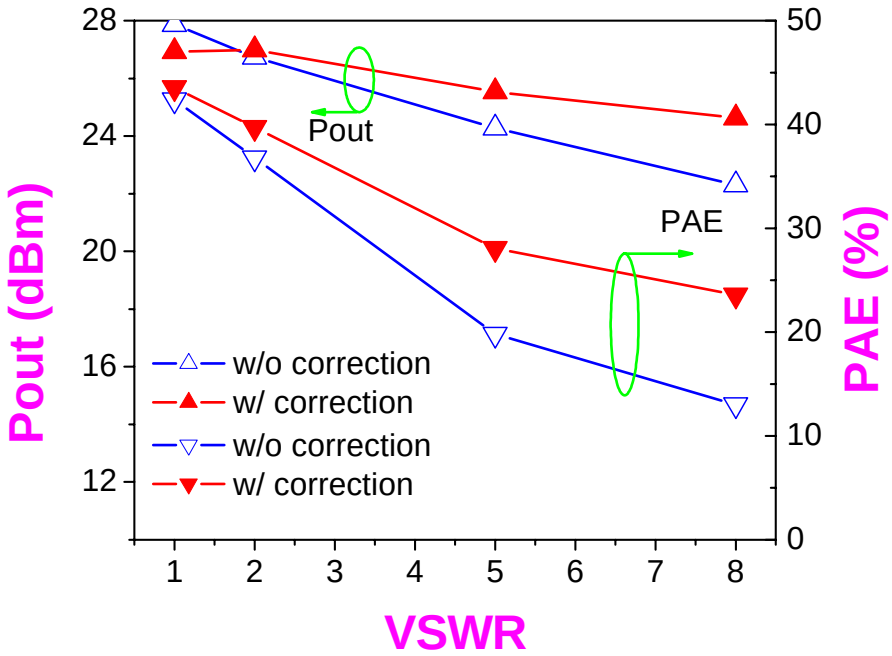
Experimental Setup

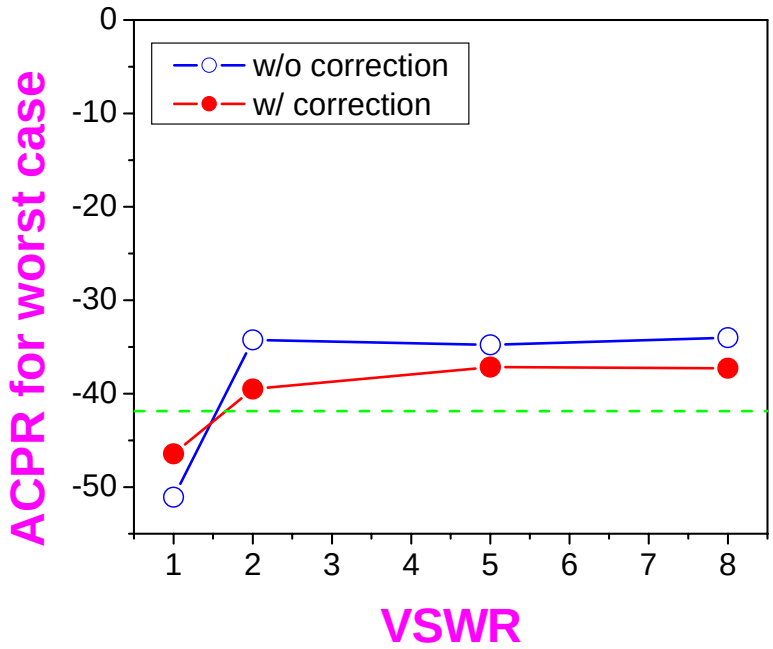




Improvement of Power Amplifier Performance

- Average results for VSWRs with different phase



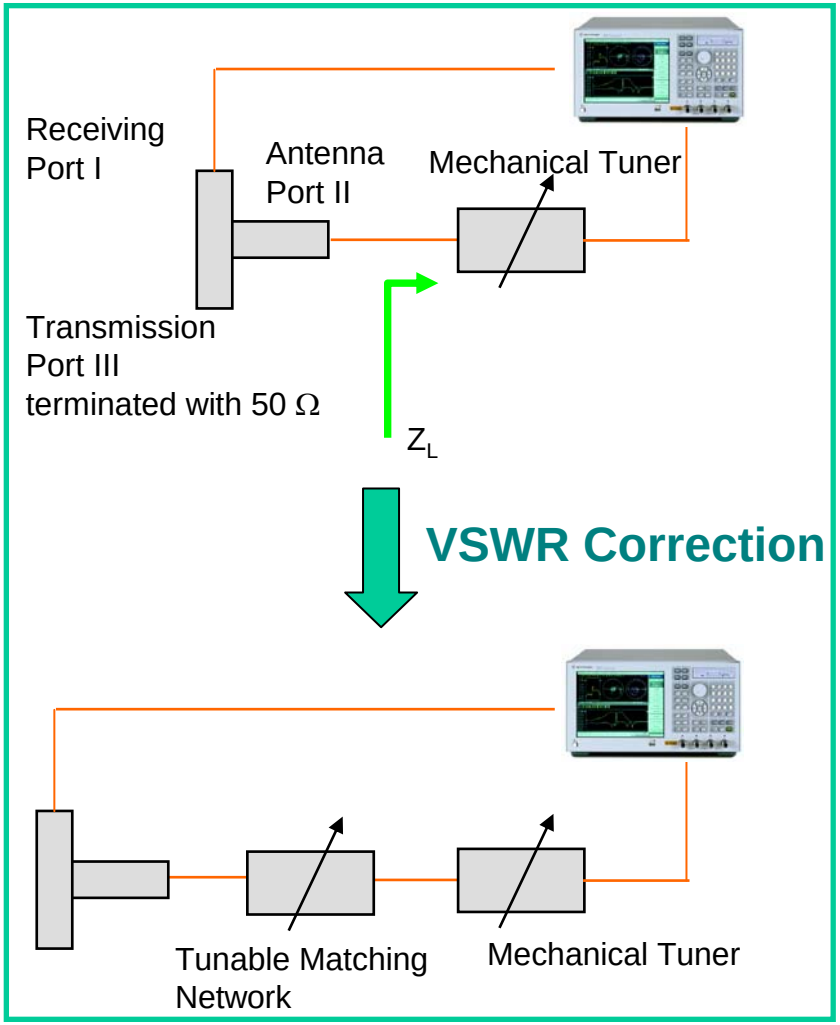


For 8:1 VSWR

- Pout improved by 2.8 dB
- PAE improved by × 2 times
- Worst ACPR reduced 4 dB

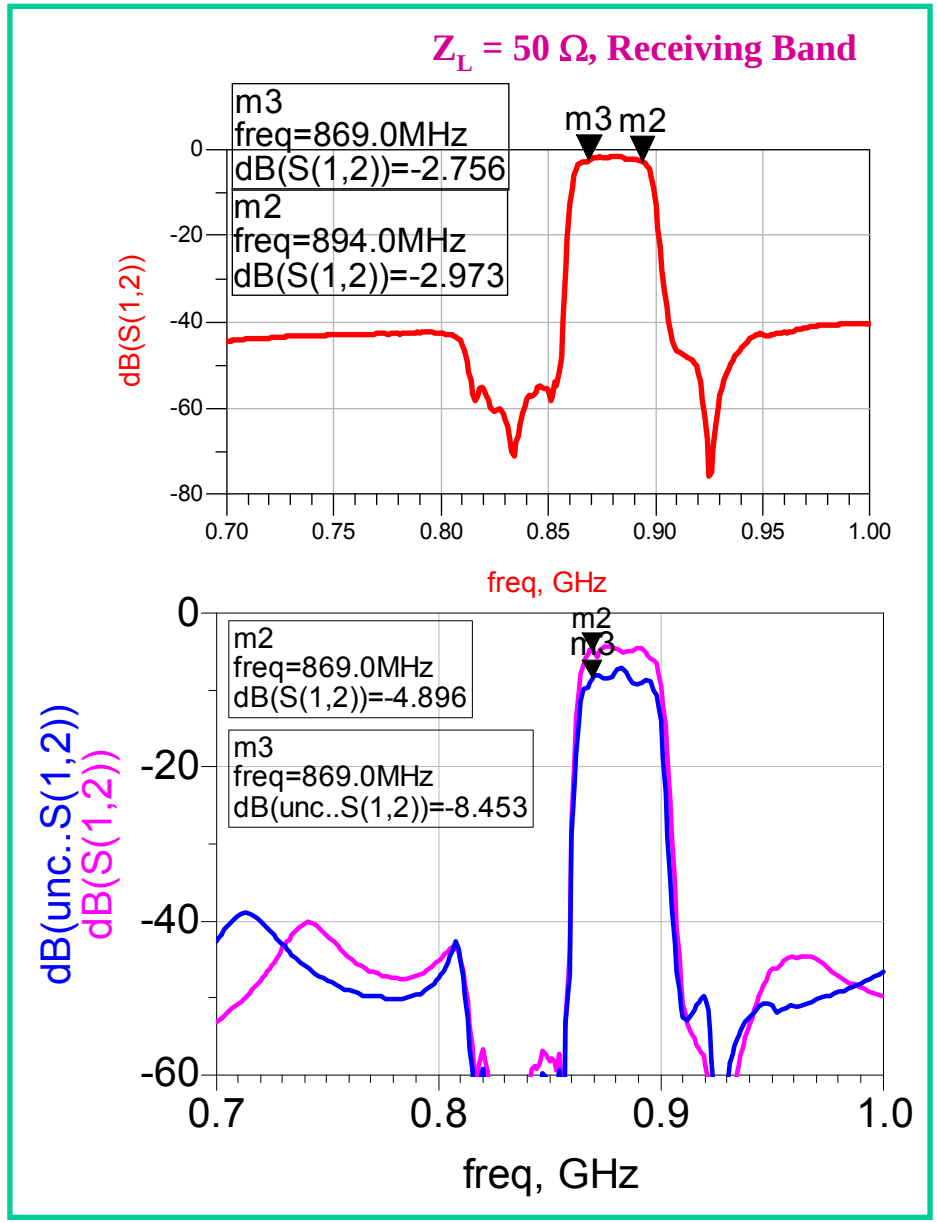
Impact of Load Impedance Mismatch on Duplexer

(EPCOS B4224 SAW Duplexer Filter: Measured Data)



Average results for 8:1 VSWR

–S12 ↑ 2.5 dB



Summary

- Antenna load impedance mismatch has been effectively reduced using a tunable matching network implemented using SOS switches.

- A method has been developed to measure the antenna load impedance based on measurement of the voltages along a transmission line.

- With closed loop correction of the impedance mismatch, the output power, PAE and linearity of a PA have been improved; the in-band insertion of duplexer has been reduced.