Transparent Repeater for GSM 1800

Hochfrequenztechnik
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Outline

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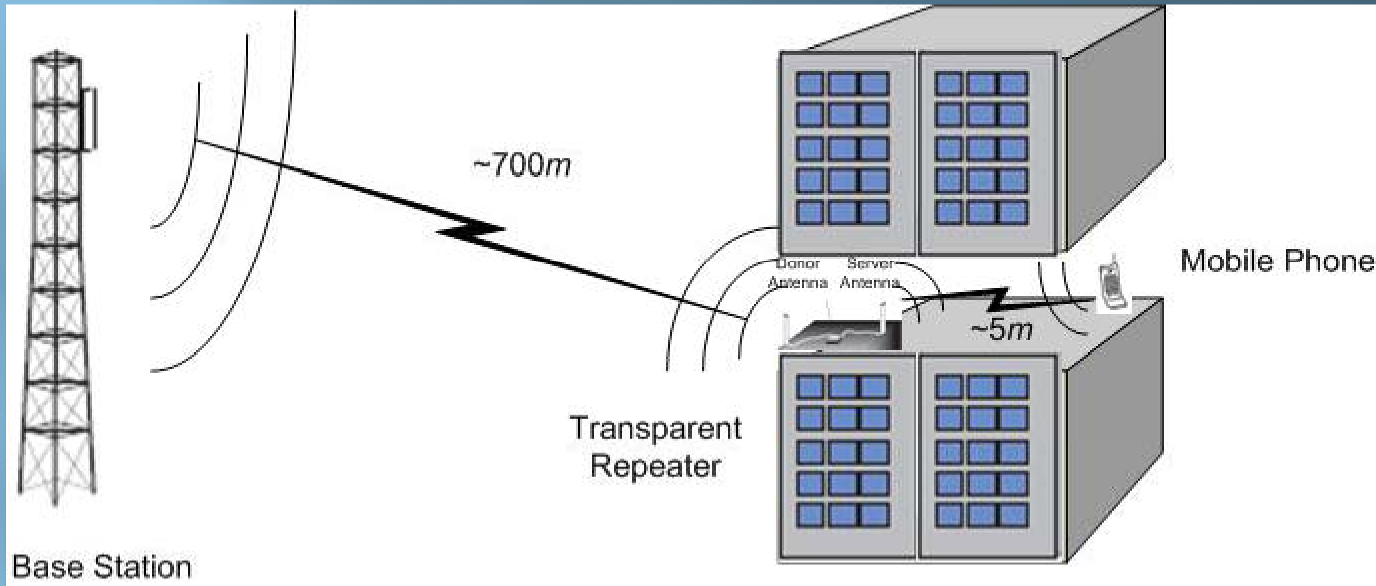
Motivation

HFT

- EM-waves attenuation as they travel into "shadowed" areas (e.g., indoors environment)
  - Reinforced concrete structures and metallic layered windows (specific case)
- All these circumstances added up could lead to a break in the communication link between BS and MS
- Improvement of the signal through the use of Transparent Repeaters
  - Amplification without affecting the signal and its frequency components (e.g., modulation or demodulation)
  - 3 Basic components: antennas, duplexer, amplifiers

Model of the Situation

Estimated required gain



Path	Distance (m)	Attenuation (dB)
BS-MS	705	74 (goal)
BS-DA	700	62
SA-MS	5	39
	705 (total)	101 *

Friis Equation

$$\frac{P_{receiver}}{P_{transmitter}} = G_t G_r \cdot \left(\frac{\lambda}{4\pi R}\right)^2$$

Model of the Situation

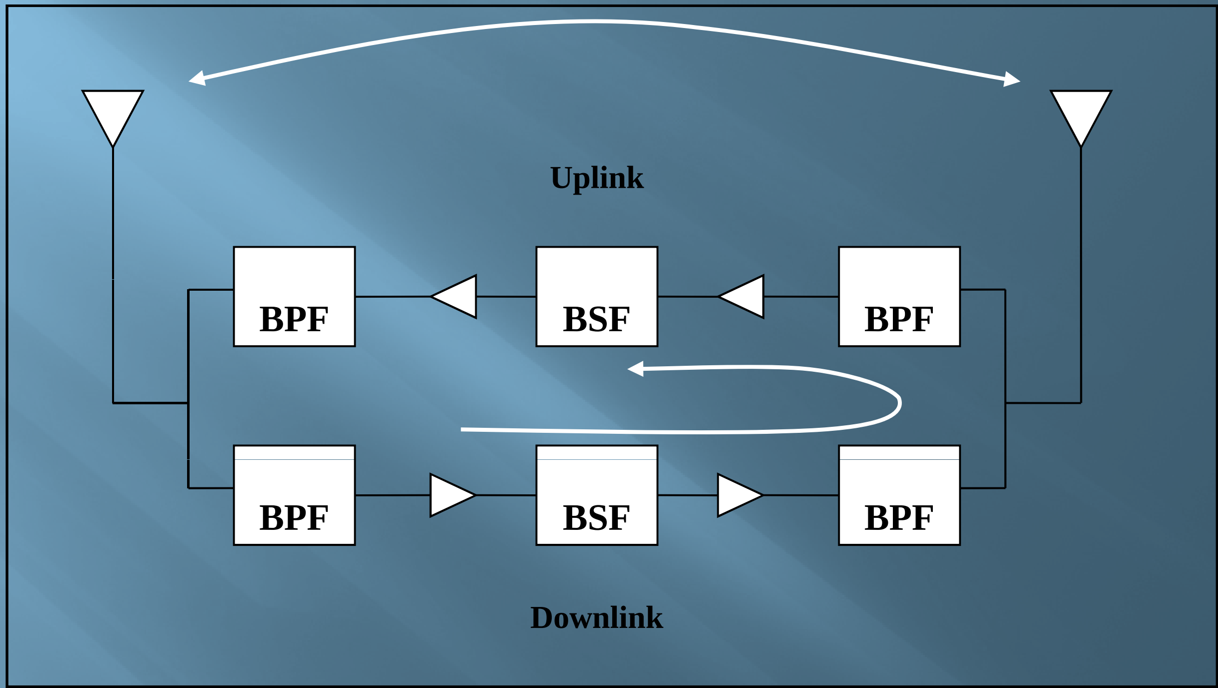
Estimated required gain

Signal Level Plan – Repeater			
Path	***Attenuation min (dB)***	***Attenuation Max (dB)***	***Comments***
Cable from donor antenna to repeater (5*m*)	2	2	RG213, 40*dB*/100*m* @ 1,8*GHz*
SMA connector	0	0	Neglectable
Duplexer 1	5	8	S21 Duplexer
Amplifier 1 (VSWR)	0.07	0.07	VSWR=1.3, Trans. 0.07*dB*
Blocking Filter	1	3	Estimate
Amplifier 2 (VSWR)	0.07	0.07	VSWR=1.3, Trans. 0.07*dB*
Duplexer 2	5	8	S21 Duplexer
SMA connector	0	0	Neglectable
Cable from repeater to server antenna (10*m*)	4	4	RG213, 40*dB*/100*m* @ 1,8*GHz*
Total	**17.14**	**25.14**	

*	**Level Plan**	**Attenuation BS-Donor**	**Attenuation Server-MS**	**Total Losses**	**Desired Overall Gain**
Attenuation min.	17*dB*	62*dB*	39*dB*	118*dB*	**~ 44*dB***
Attenuation Max.	25*dB*	62*dB*	39*dB*	126*dB*	**~ 52*dB***

Model of the Situation

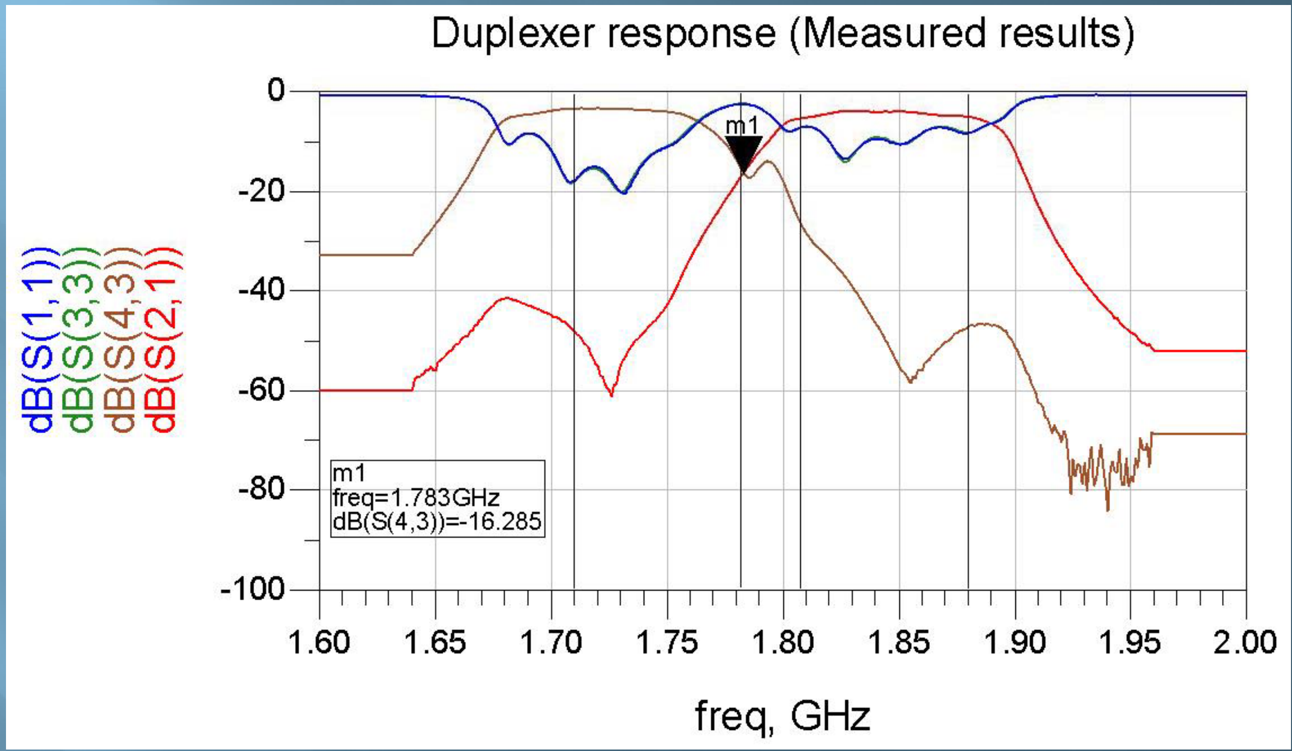
Limitations



- Inner coupling of the elements
- Proper isolation between the antennas
- Excessive gain could produce oscillations
- Oscillations lead to instability

Model of the Situation

Limitations



- Duplexer response not steep enough to reject some components
- Center frequency shifted approximately 10*MHz* to the left

Model of the Situation

Actual attainable gain

Neglecting the losses due to the bandstop filter:

$$2(-15dB)+2(-15dB)+4\cdot Gain_a \leq 0$$

$$Gain_a \leq 15dB$$

- Well below the original desired gain value
- Improvement by adding the bandstop filter
- Center frequency will remain a shortcoming
- Possible losses of some channels in the upper band of the uplink

Implementation of a BSF

Design and Optimization in ADS

- 5-Resonator Bandstop Filter with half-wavelength resonators
- Extremely low Fractional Bandwidth ~1,4%

$$FBW = \frac{f_2 - f_1}{f_0} \approx 1.39\%$$

- Greater number of resonators → steeper response (bad forward reflection coeff.)
- Estimation of the resonator length according to

$$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\left(1 + 12 \cdot \frac{H}{W}\right)^{-0.5} + 0.04\left(1 - \frac{W}{H}\right)^2\right]$$

$$\lambda_{g0} = \frac{\lambda_0}{\sqrt{\varepsilon_{re}}} \approx 63.5mm$$

Implementation of a BSF

Design and Optimization in ADS

- Element values and normalized reactance

n	g_1	g_2	g_3	g_4	g_5	g_6
1	0.3052	1.0				
2	0.8431	0.6220	1.3554			
3	1.0316	1.1474	1.0316	1.0		
4	1.1088	1.3062	1.7704	0.8181	1.3554	
5	***1.1468***	***1.3712***	***1.9750***	***1.3712***	***1.1468***	***1.0***

$$\frac{x_1}{Z_0} = \frac{x_5}{Z_0} = 62.61$$

$$\frac{x_2}{Z_0} = \frac{x_4}{Z_0} = 52.36$$

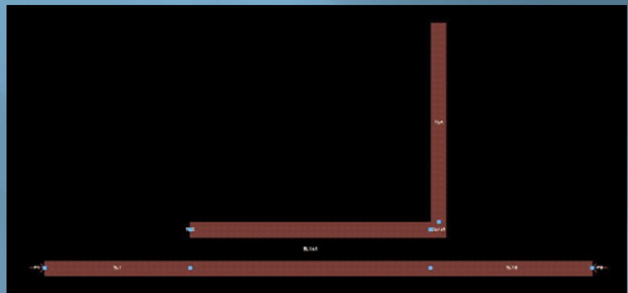
$$\frac{x_3}{Z_0} = 36.35$$

$$x_i = \omega_0 L_i = \frac{1}{\omega_0 C_i} = Z_0 \left(\frac{Z_U}{Z_0}\right)^2 \cdot \frac{g_0}{g_i \Omega_c FBW}$$

Implementation of a BSF

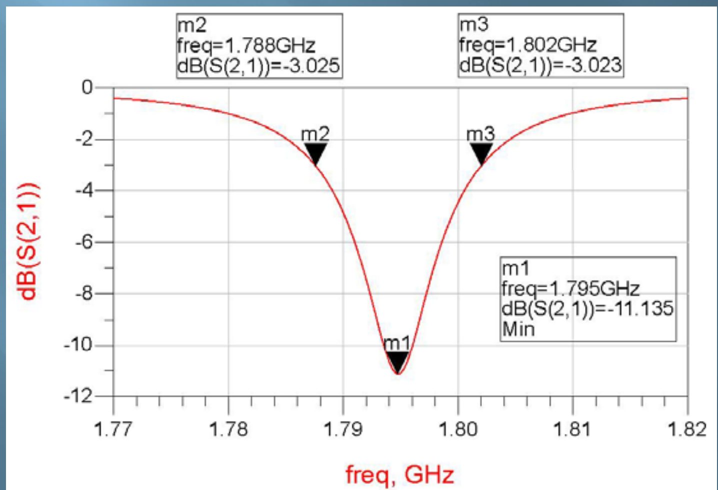
Design and Optimization in ADS

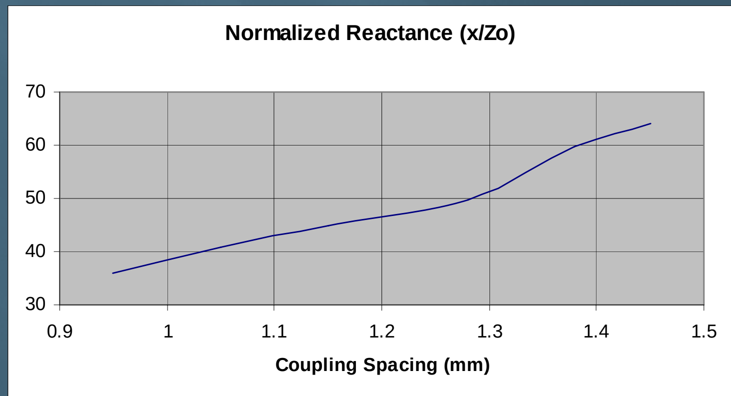
- Coupling spacing of the resonators is associated to the normalized reactance



$$\frac{x}{Z_0} = \frac{\omega_0}{2 \cdot \Delta\omega_{3dB}} = \frac{f_0}{2 \cdot \Delta\omega_{3dB}}$$

- The 3-*dB* cut-off frequency changes as we vary the coupling spacing

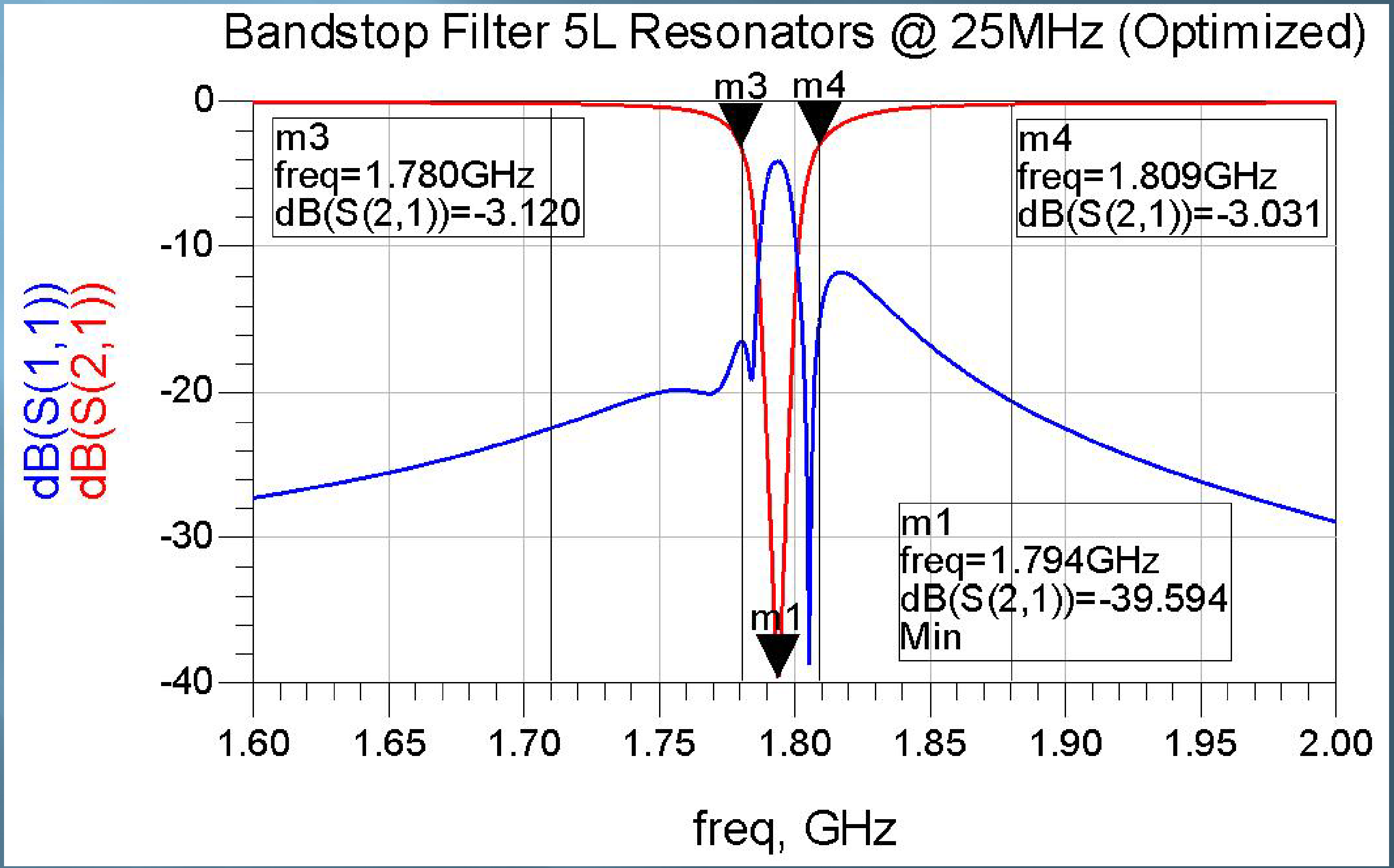




Implementation of a BSF

Design and Optimization in ADS

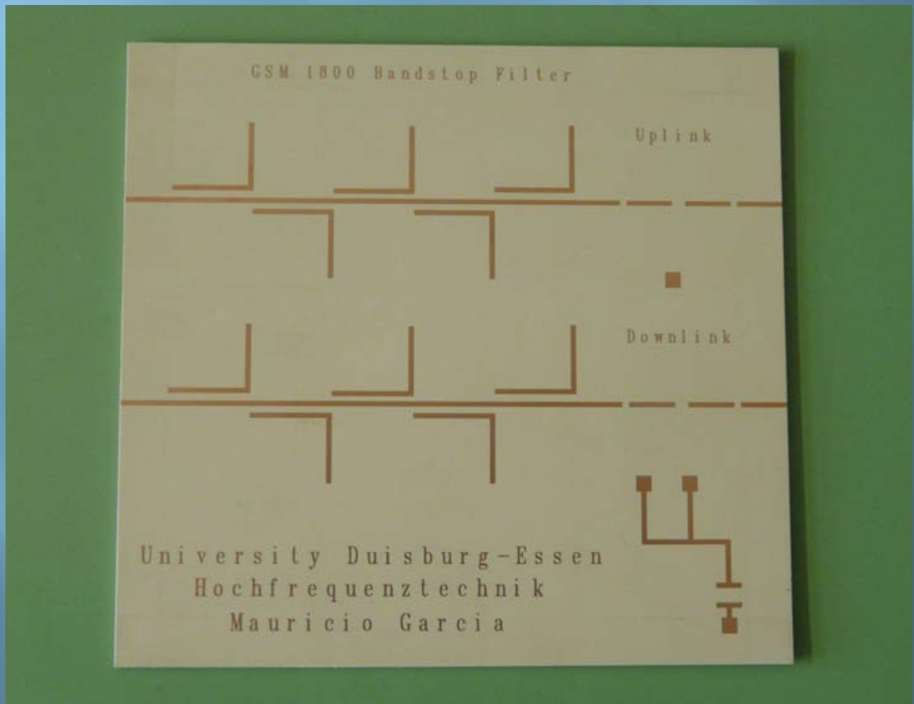
- Simulated results after the optimization

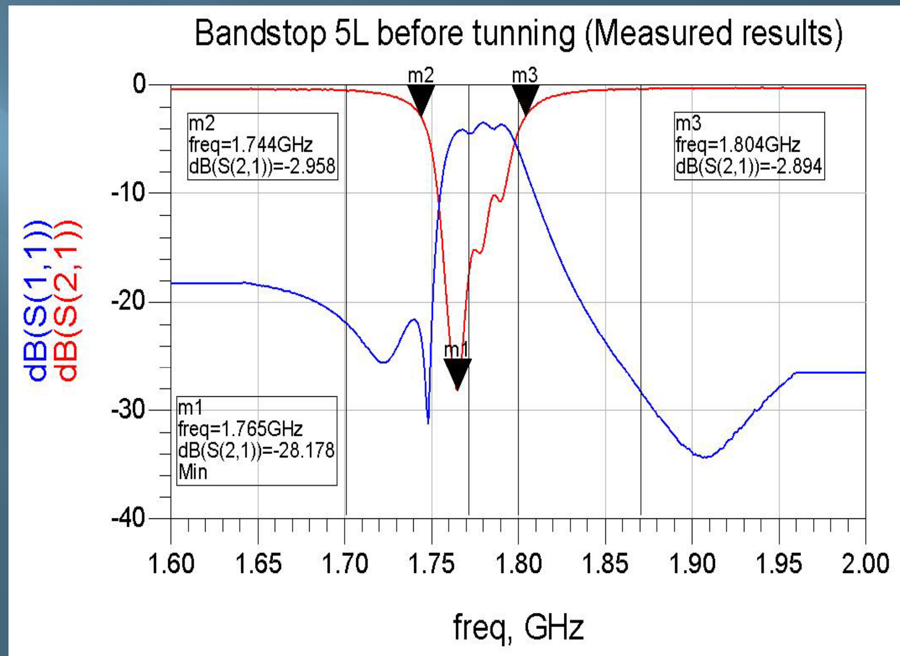


Implementation of a BSF

Tuning and measured results

- Realized structure after the simulation and its corresponding measured response

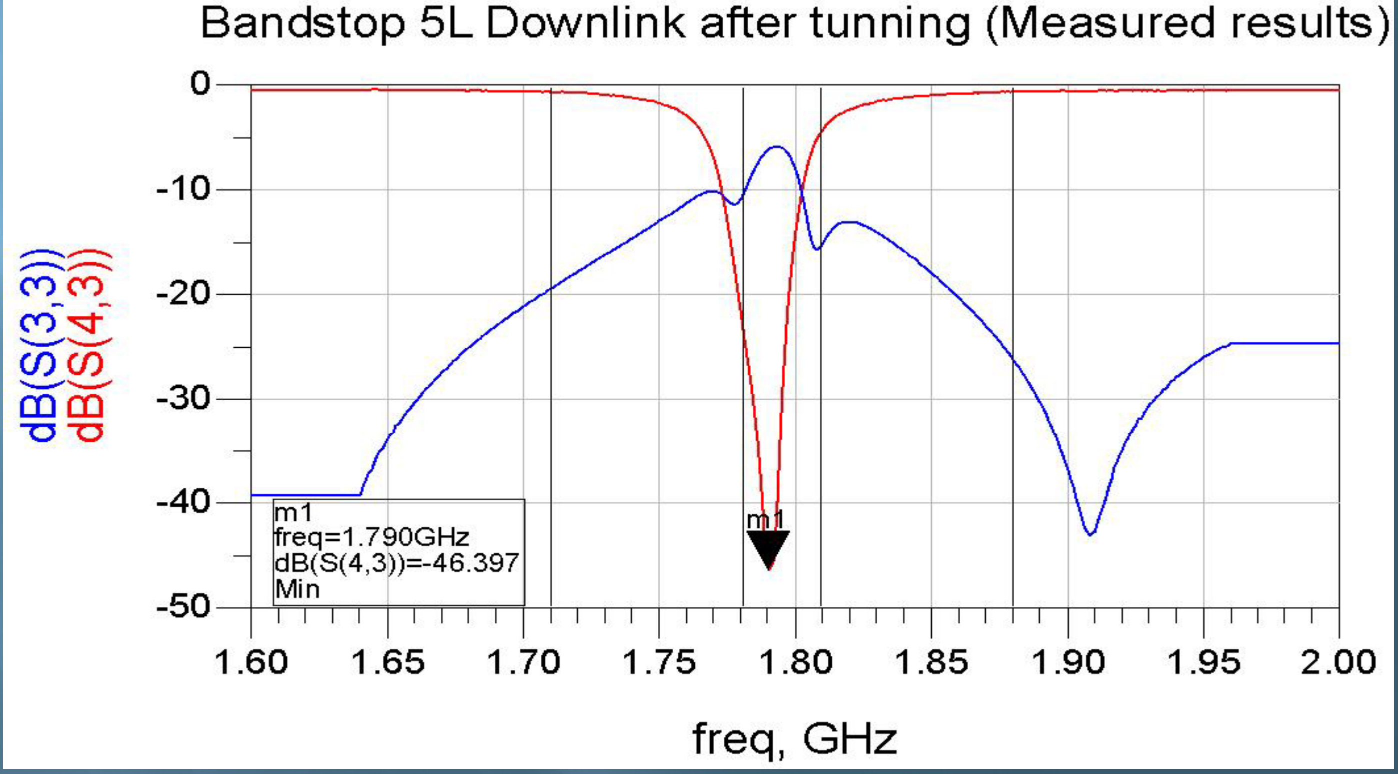




Implementation of a BSF

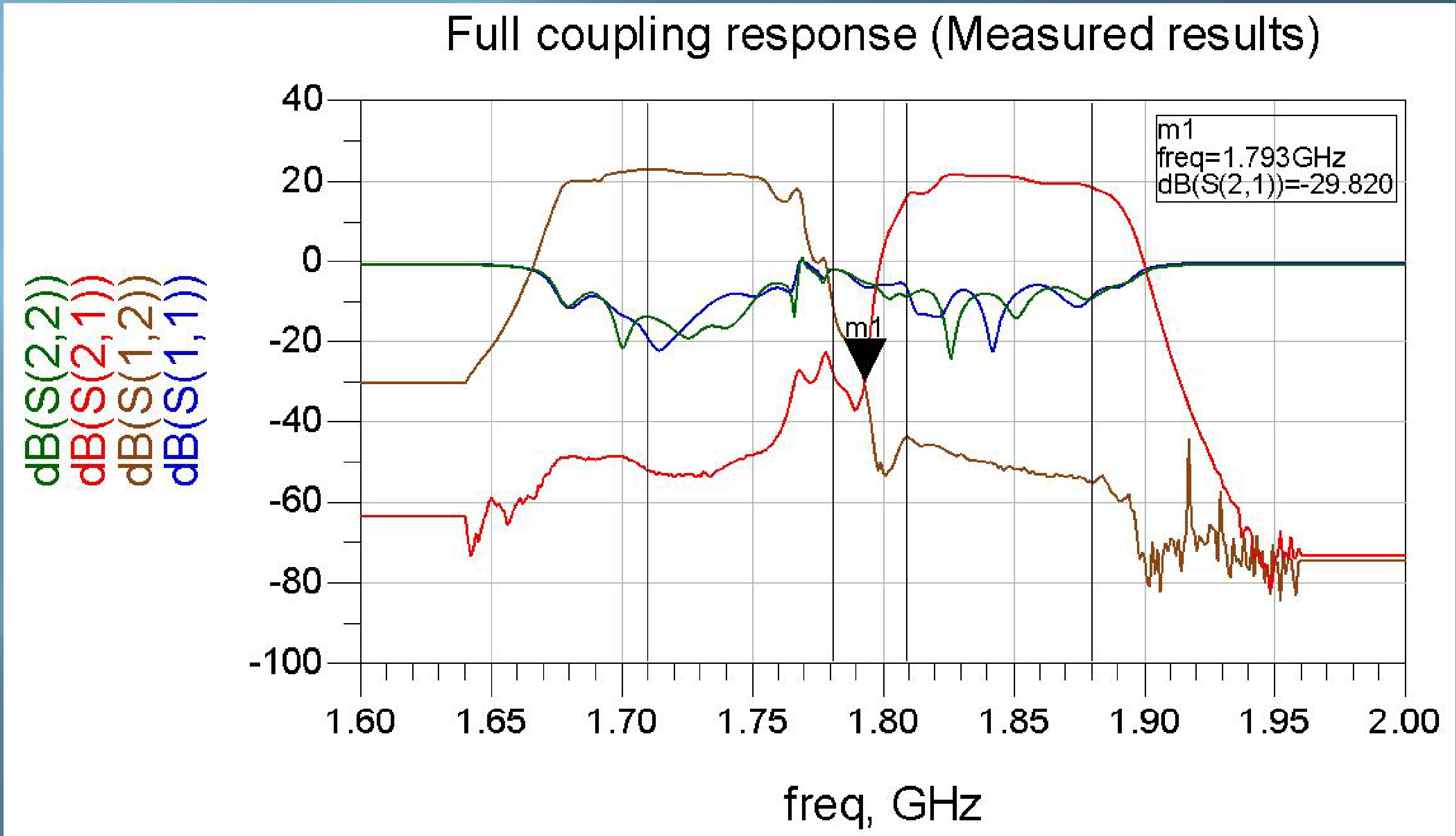
Tuning and measured results

- Tuning is necessary in order to shift the center frequency towards the right
- Trimming the ends of the resonators is a delicate process that requires aid of a microscope



Repeater Measured Result

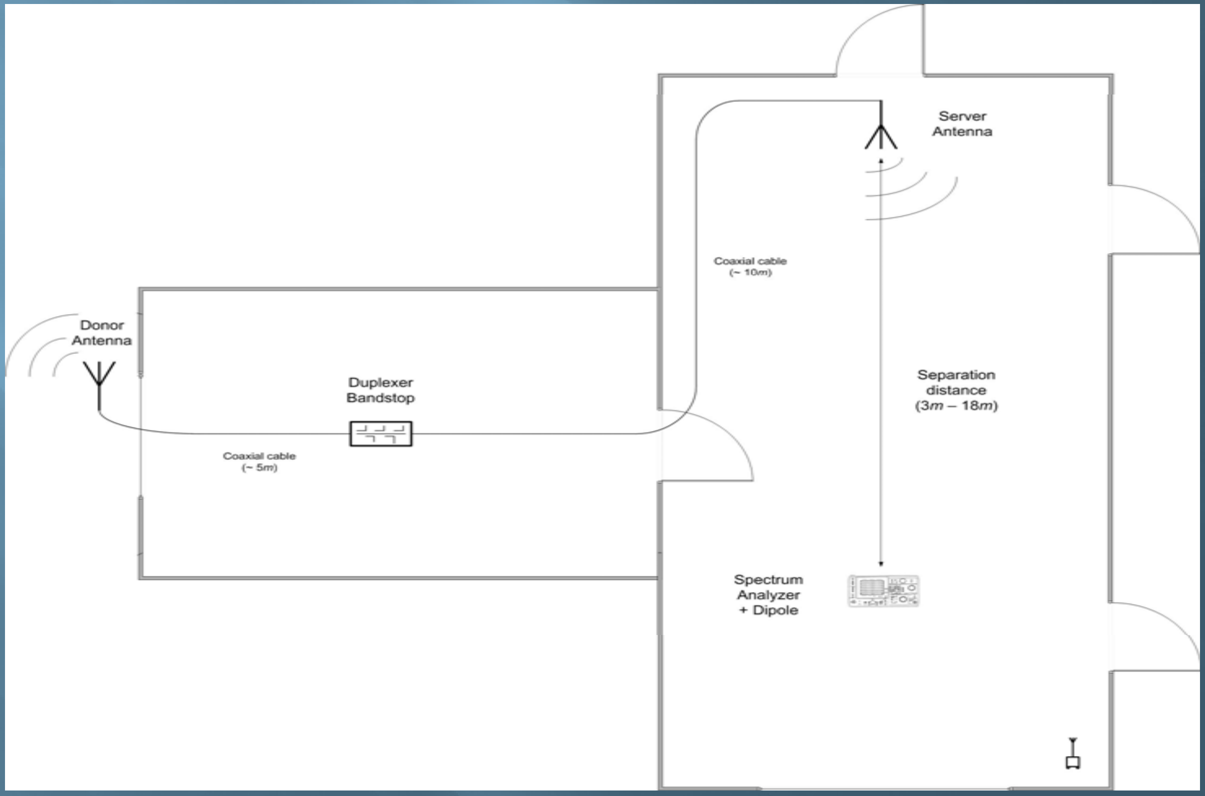
- Coupling between Duplexer and Bandstop Filters measured results with a Network Analyzer



Repeater Measured Result

System setup and floor plan

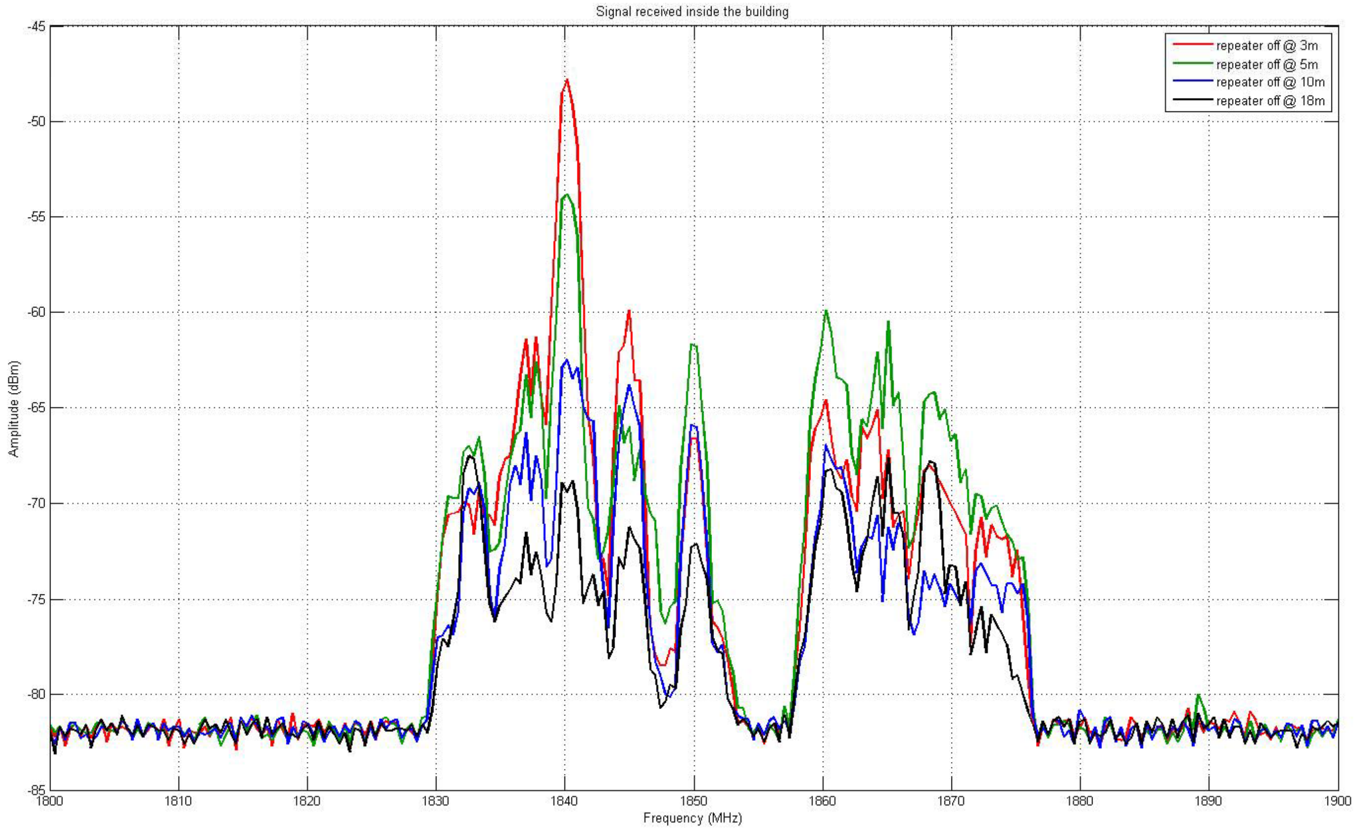
- Measurements were made with help of two BS panel antennas as donor and server (~14*dBi* gain)
- A dipole antenna (1.8*GHz*) attached to a spectrum analyzer was used to record the measurements



Repeater Measured Result

Measured results

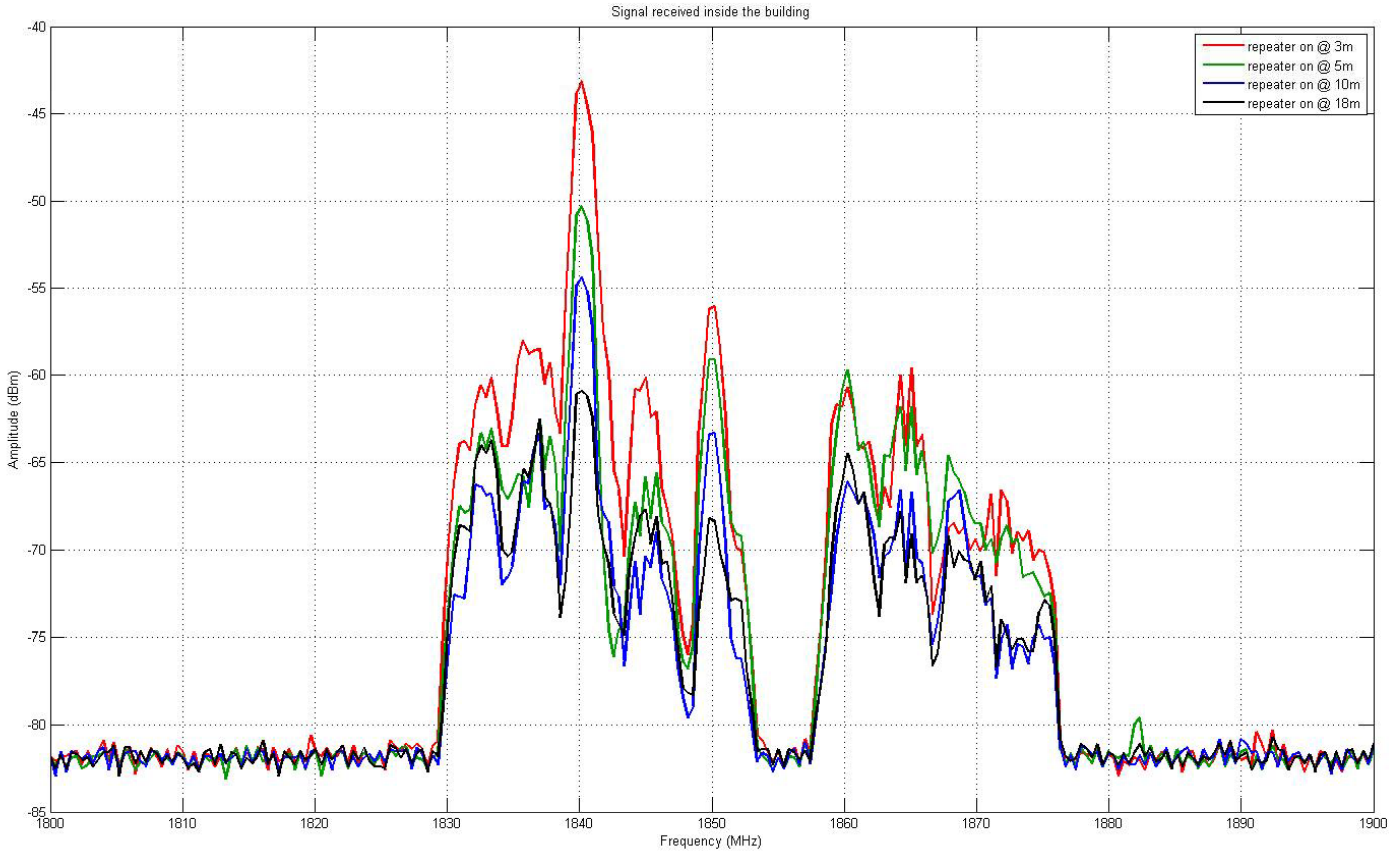
- Without repeater



Repeater Measured Result

Measured results

- With repeater



Discussion

- We considered the worst case scenario while modeling the system (more precise model for future work)
- Microstrip substrate has a larger permittivity than appears on the data sheet (estimated)
- Minimum improvement on the received signal with the use of the transparent repeater (~5 to 10*dBm*)
- It is possible to raise the gain of the amplifiers from ~32 to 40*dB* without need of introducing new elements
- The greater the gain, the more pronounced the ripples in the measured response (interaction between elements)
- After ~45dB gain we recorded oscillations (instability)
- Hard to record measurements with accuracy due to the changing signal strength coming from the BS

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Thank you