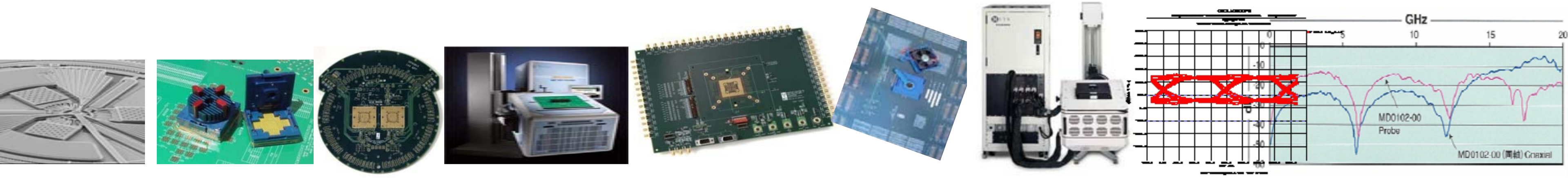

Design of experiments using spring probe parameters for optimized socket bandwidth

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Agenda

- Problem definition
- Seven principles of interconnect design for optimized insertion loss
- Key input variables and output variable
- Design of experiments
- Experimental results
- Analysis of results
- Optimized insertion loss model
- Confirmation run to verify model
- Conclusions

Problem Definition

- There is no established relation between critical spring probe parameters and their influence on signal integrity.
- There is no baseline reference and a starting point for spring probe design which is an everyday need due to emerging new application requirements.

Seven principles of interconnect design for optimized insertion loss

Eric Bogatin says:

1. Match characteristic impedance of socket to 50 Ohms
2. Keep the impedance constant through socket
3. Optimize (minimize) pad stack up capacitance
4. Keep socket short
5. Dielectric loss of socket not critical
6. Conductor loss of socket not critical
7. Contact resistance of socket not critical

Key input variables and output variable

- Input variable
  - Spring pin length (1mm to 4mm)
  - Spring pin diameter (0.25mm to 0.35mm)
  - Ground pattern
    - C1 (G-S-G)
    - C2 $\begin{pmatrix} & G & \\ G- & S & -G \\ & G & \end{pmatrix}$
- Output variable
  - Bandwidth (GHz) at -1dB Insertion loss

Design of experiments

Study Type	**Factorial**
Runs	**8**
Initial Design	**2 Level Factorial**
Blocks	**No Blocks**
Center Points	**0**
Design Model	**3FI**

Name	Units	Type	Low Actual	High Actual	Low Coded	High Coded	Mean	Std. Dev.
Diameter	mm	Numeric	0.25	0.35	-1	1	0.3	0.05
Length	mm	Numeric	1	4	-1	1	2.5	1.5
Ground		Categoric	C1	C2			Levels:	2

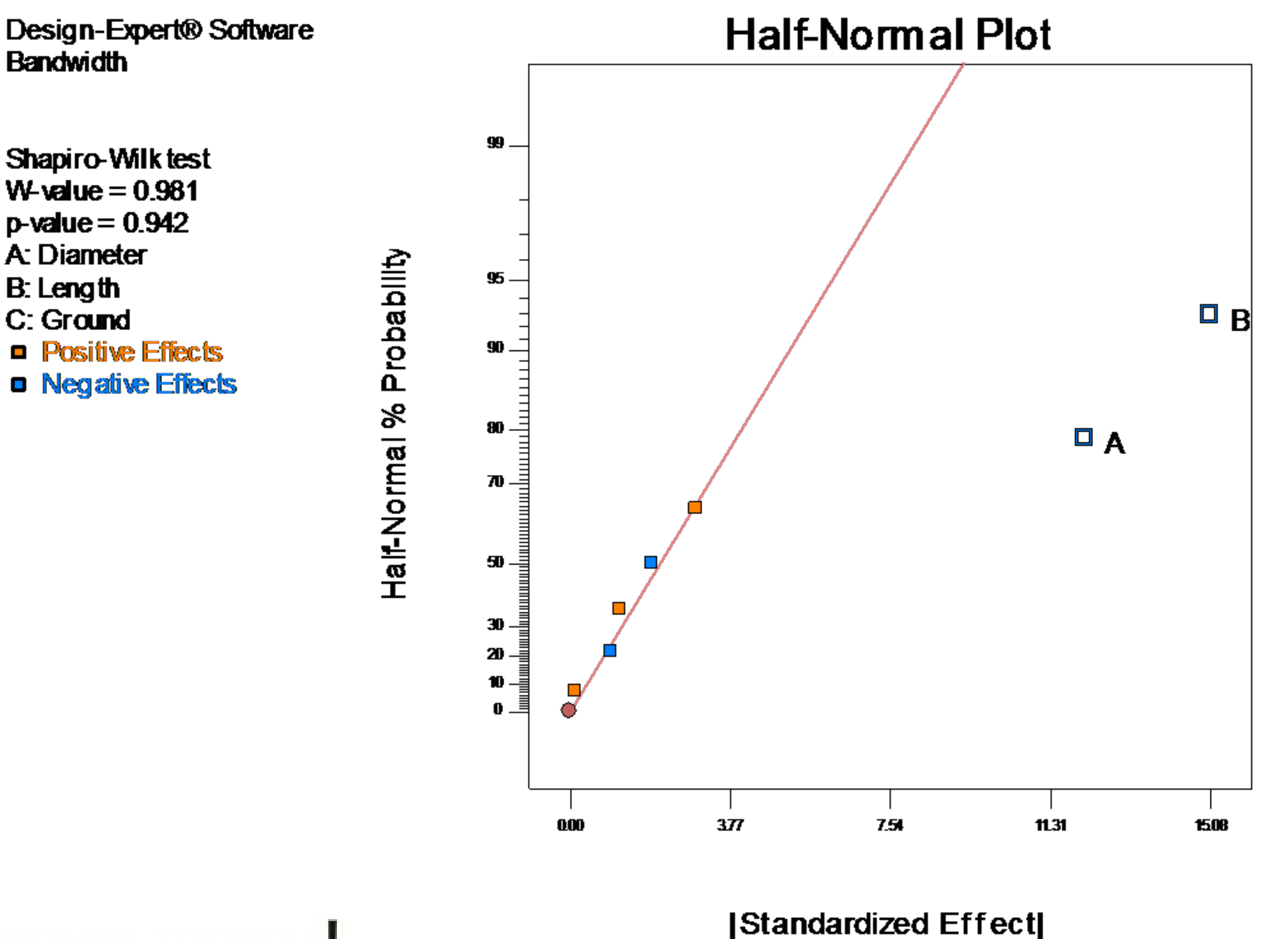
Design of experiments

Standard Order	Run Order	Block	Diameter (mm)	Length (mm)	Ground pattern	Bandwidth (GHz)
7	1	Block 1	0.25	4	C2	
4	2	Block 1	0.35	4	C1	
3	3	Block 1	0.25	4	C1	
8	4	Block 1	0.35	4	C2	
5	5	Block 1	0.25	1	C2	
6	6	Block 1	0.35	1	C2	
2	7	Block 1	0.35	1	C1	
1	8	Block 1	0.25	1	C1	

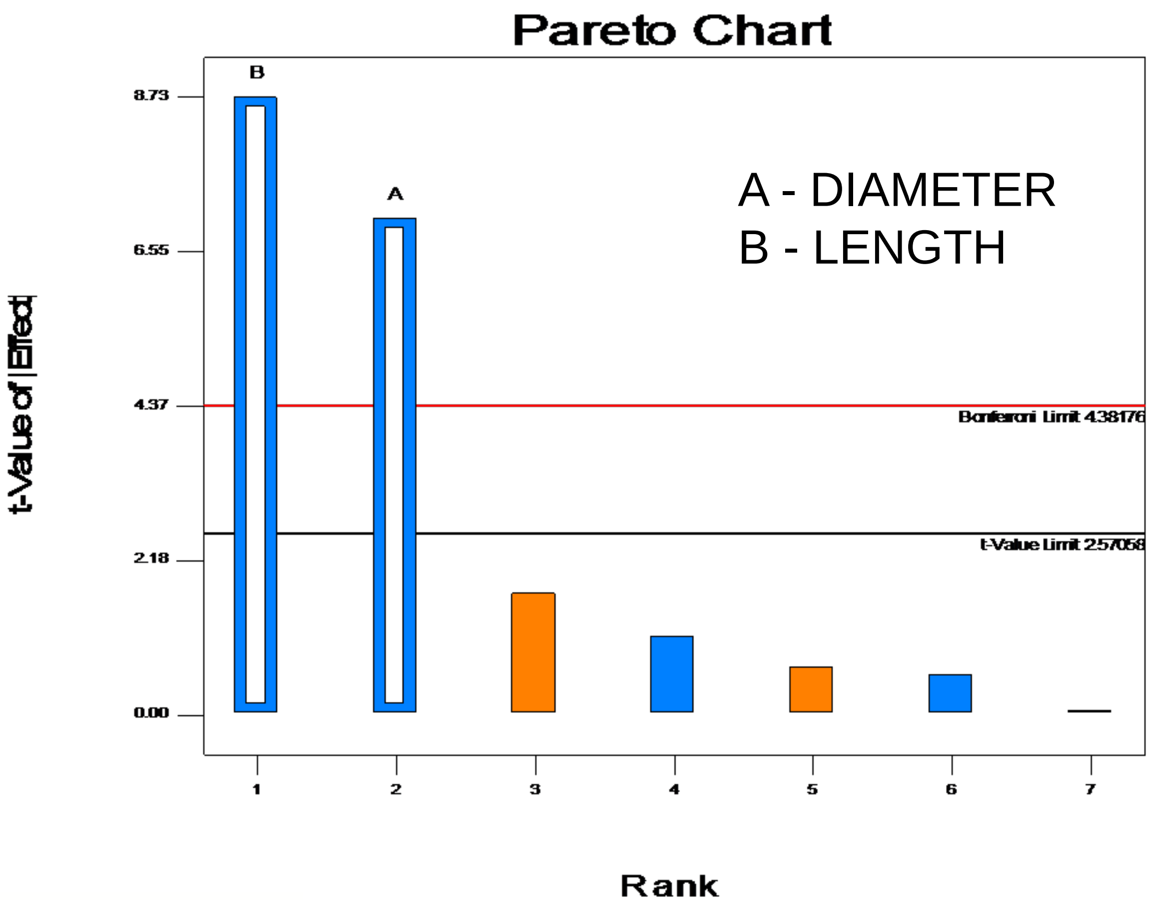
Experimental results

Standard Order	Run Order	Block	Diameter (mm)	Length (mm)	Ground pattern	Bandwidth (GHz)
7	1	Block 1	0.25	4	C2	14
4	2	Block 1	0.35	4	C1	5.6
3	3	Block 1	0.25	4	C1	13.9
8	4	Block 1	0.35	4	C2	4
5	5	Block 1	0.25	1	C2	31
6	6	Block 1	0.35	1	C2	14.8
2	7	Block 1	0.35	1	C1	19
1	8	Block 1	0.25	1	C1	33

Analysis of results



Analysis of results



Analysis of results

Response	Bandwidth					
ANOVA for selected factorial model						
Source	Sum of Squares	df	Mean Square	F Value	p-value, Prob > F	
Model	748.5425	2	374.27125	62.78402181	0.0003	significant
A-Diameter	294.03125	1	294.03125	49.3237576	0.0009	
B-Length	454.51125	1	454.51125	76.24428601	0.0003	
Residual	29.80625	5	5.96125			
Cor Total	778.34875	7				

The Model F-value of 62.78 implies the model is significant. There is only a 0.03% chance that a "Model F-Value" this large could occur due to noise.

Values of "Prob > F" less than 0.0500 indicate model terms are significant.
In this case A, B are significant model terms.
Values greater than 0.1000 indicate the model terms are not significant.

Std. Dev.	2.4415671		R-Squared	0.961705791
Mean	16.9125		Adj R-Squared	0.946388107

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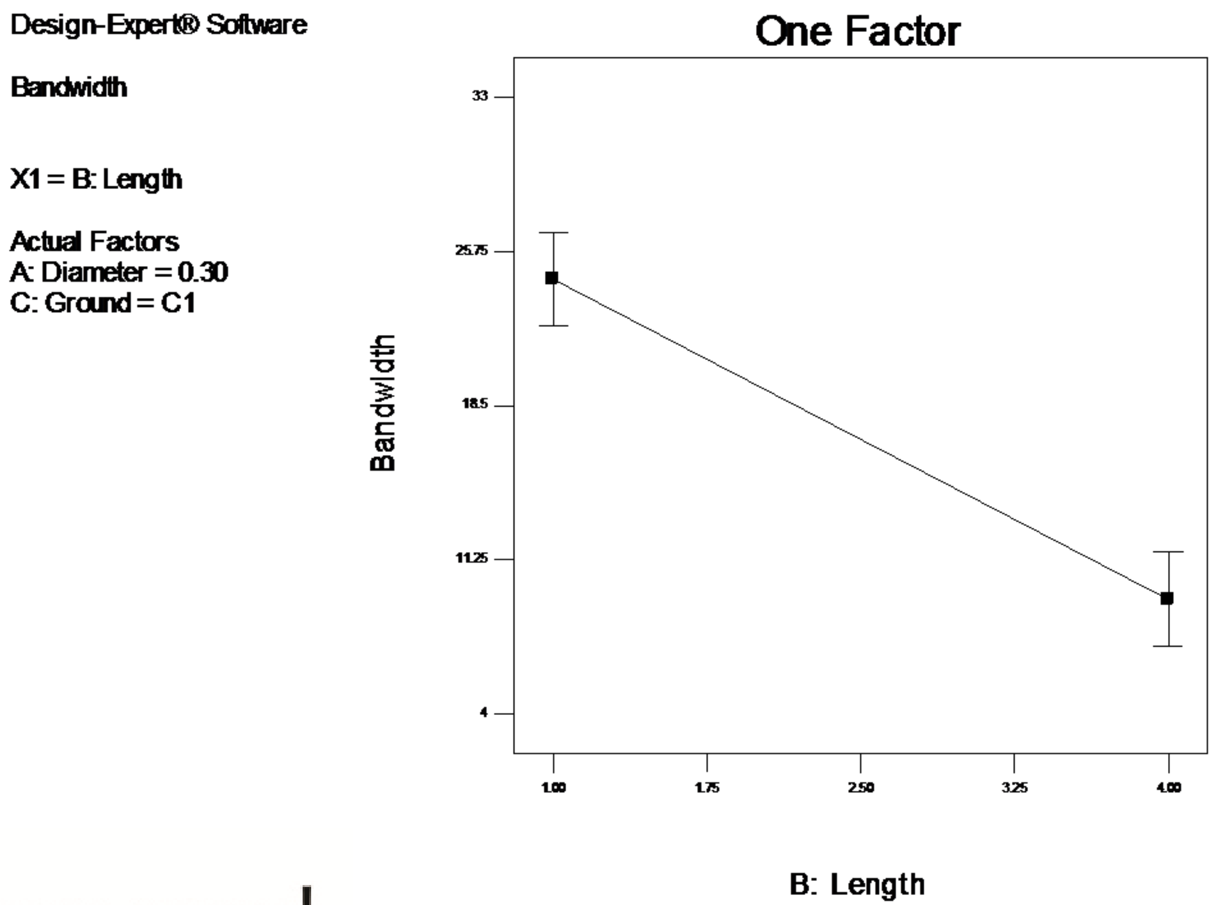
Optimized insertion loss model

Bandwidth = +65.85000
-121.25000 * Diameter
-5.02500 * Length

Model valid within the following limits

Diameter: 0.25mm to 0.35mm
Length: 1mm to 4mm

Analysis of results



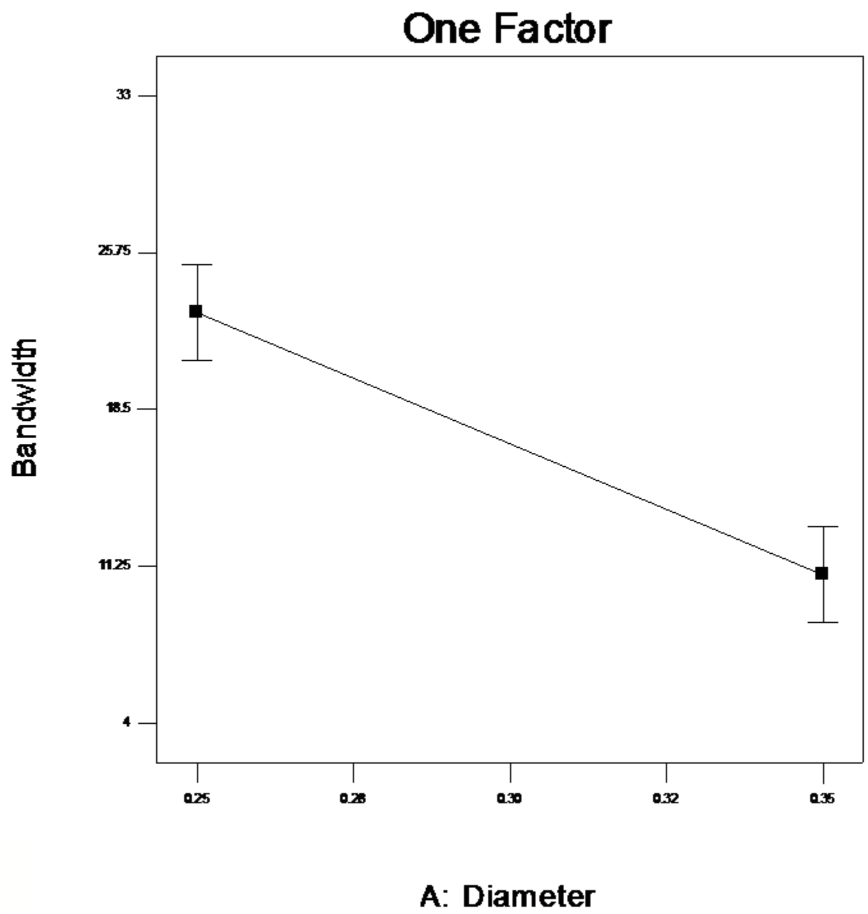
Analysis of results

Design-Expert® Software

Bandwidth

X1 = A: Diameter

Actual Factors
B: Length = 2.50
C: Ground = C1



Optimization of results

To maximize Bandwidth:

5 Solutions found						
Number	Diameter	Length	Ground*	Bandwidth	Desirability	
1	**0.25**	**1**	**C2**	**30.51248841**	**0.914223738**	**Selected**
2	0.25	1	C1	30.51248775	0.914223716	
3	0.25	1.03	C2	30.36742561	0.909221573	
4	0.25	1.03	C1	30.34746318	0.908533213	
5	0.25	1.18	C2	29.6219383	0.883515114	
*Has no effect on optimization results.						

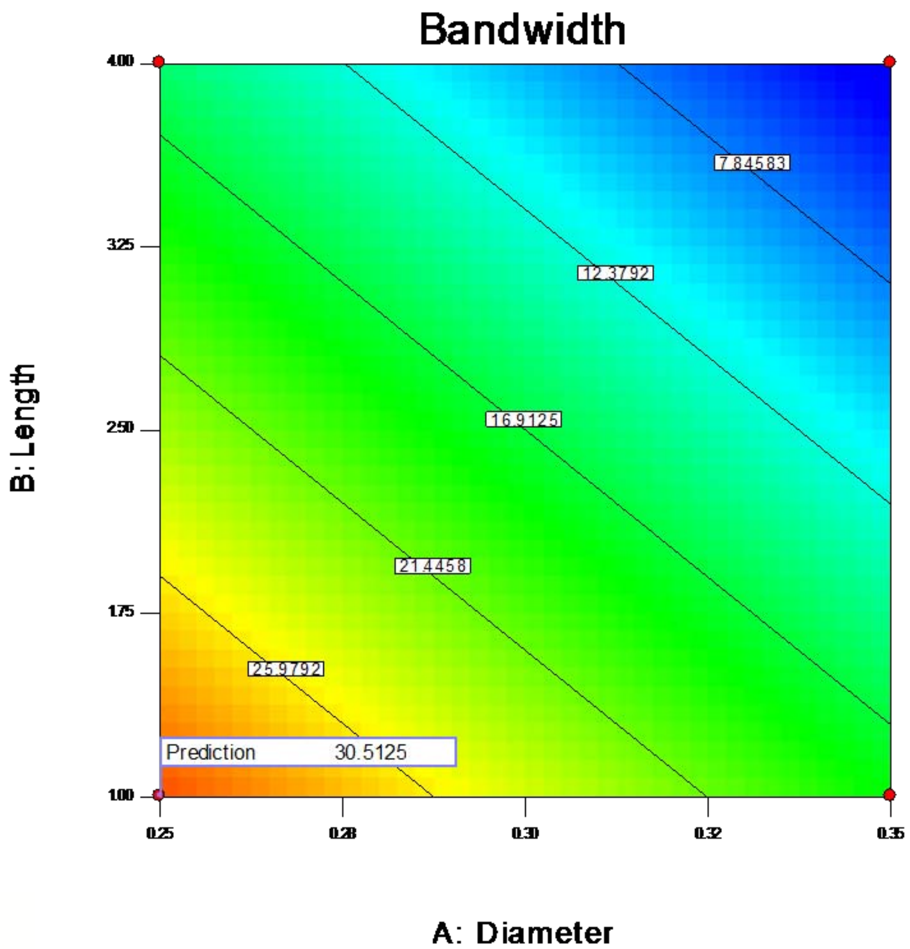
Optimization of results

Design-Expert® Software

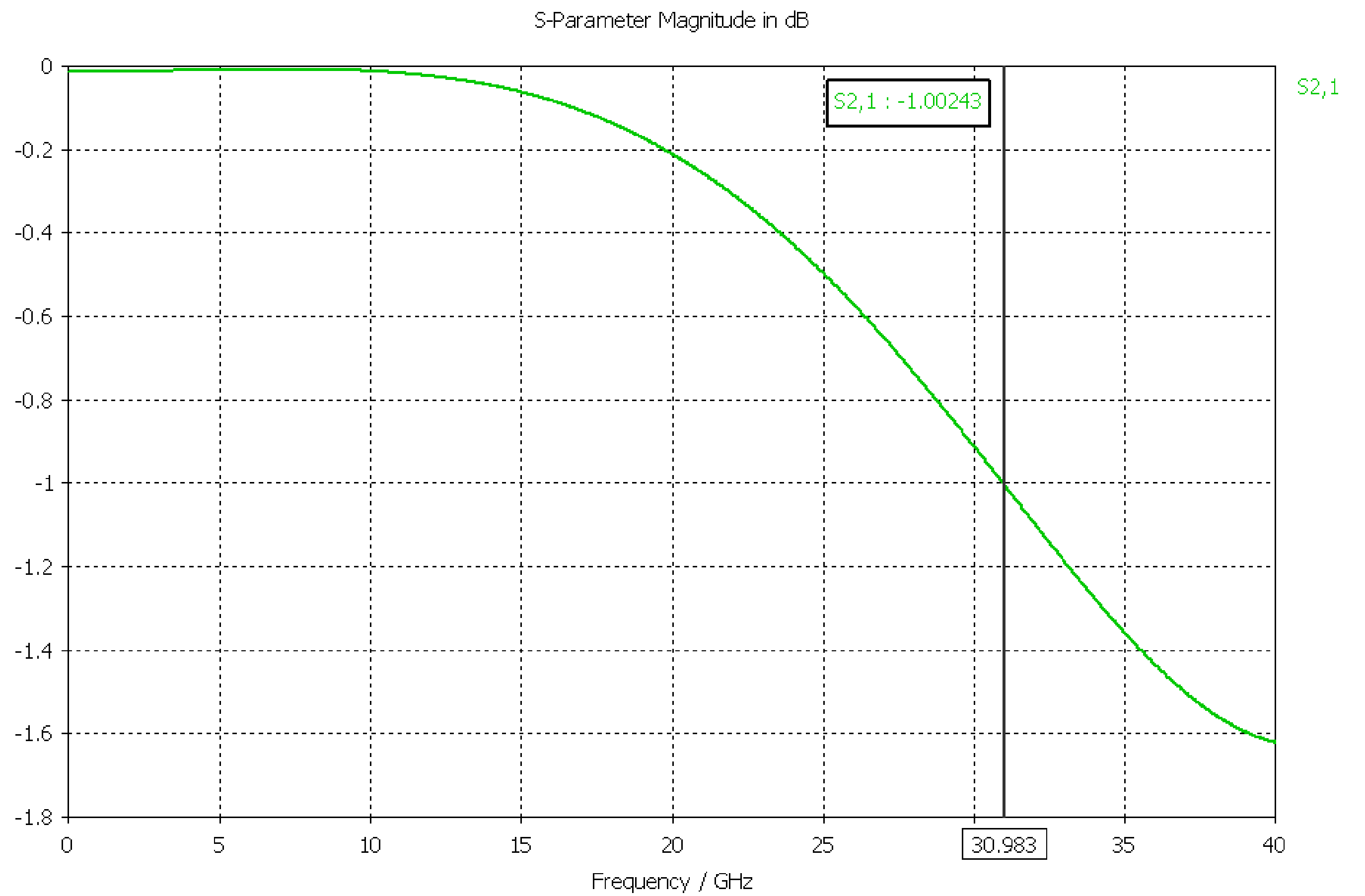
Bandwidth
● Design Points
33
4

X1 = A: Diameter
X2 = B: Length

Actual Factor
C: Ground = C2



Confirmation run to verify model

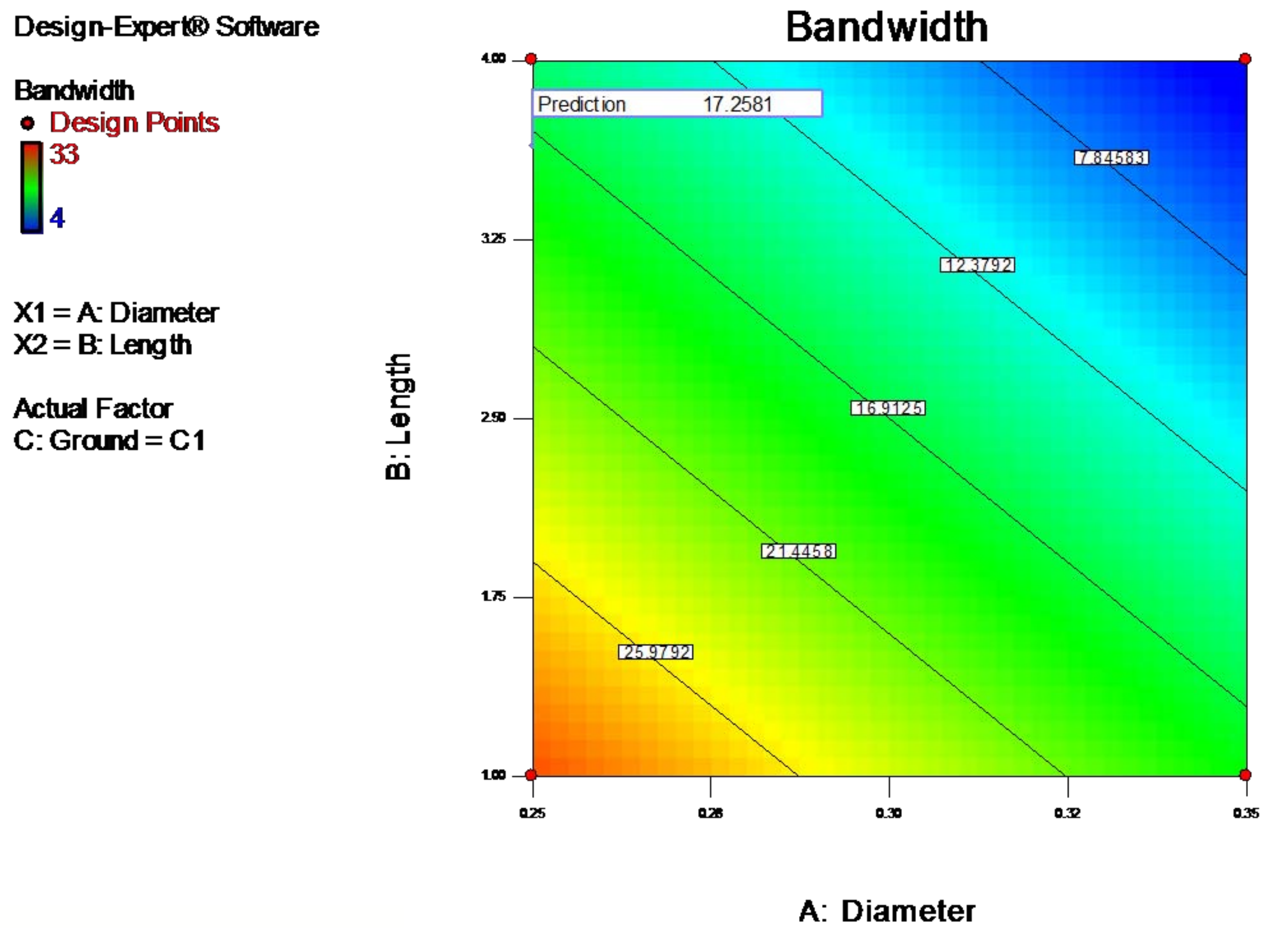


Optimization of results

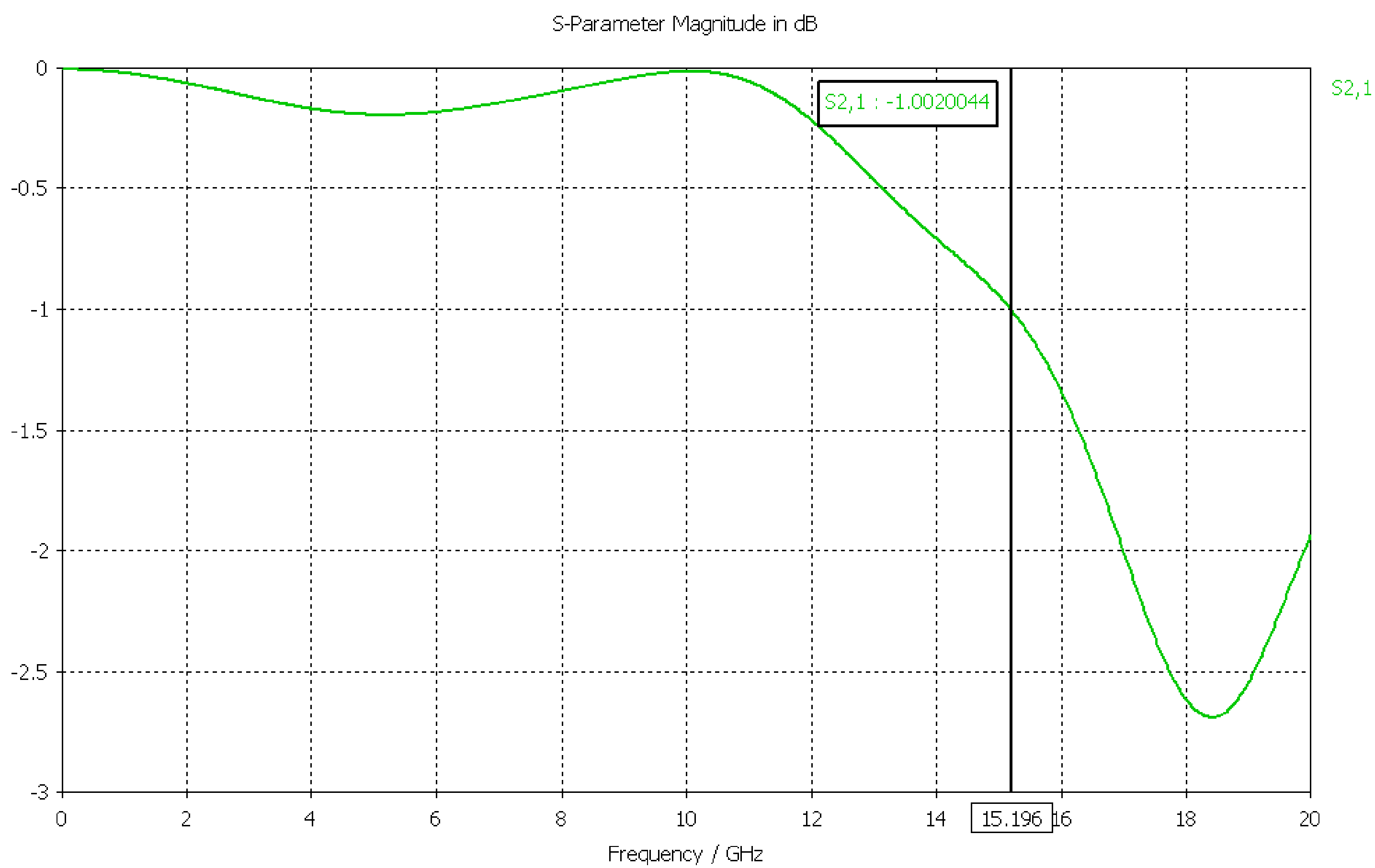
To maximize Bandwidth and Length:

9 Solutions found						
Number	Diameter	Length	Ground*	Bandwidth	Desirability	
1	**0.25**	**3.64**	**C1**	**17.25805757**	**0.63400549**	**Selected**
2	0.25	3.64	C2	17.25776855	0.634005466	
3	0.25	3.65	C2	17.19991881	0.63399974	
4	0.25	3.62	C1	17.34746791	0.633989528	
5	0.25	3.66	C1	17.13879092	0.633979894	
6	0.25	3.66	C2	17.13074513	0.633977077	
7	0.25	3.61	C1	17.41399089	0.633960073	
8	0.25	3.75	C2	16.70416448	0.633454994	
9	0.25	3.1	C2	19.96789457	0.620599198	
*Has no effect on optimization results.						

Optimization of results



Confirmation run to verify model



Conclusions

- Key input variables of spring probe and output variable are identified
- A set of experiments were designed using Design Expert Statistical Software
- Experiments were conducted and results were analyzed using Design Expert Statistical Software
- A statistical model was developed that relates spring probe parameters to optimized signal bandwidth.
- A confirmation experiment was performed to verify the validity of model.