Weekly Report

Tasks

- Utilizing NSGA-II for Multi-Objective Optimization
- Developing a UWB Antenna Model in CST MWS
- Training ANN Model
- Infill Criteria and repetitions

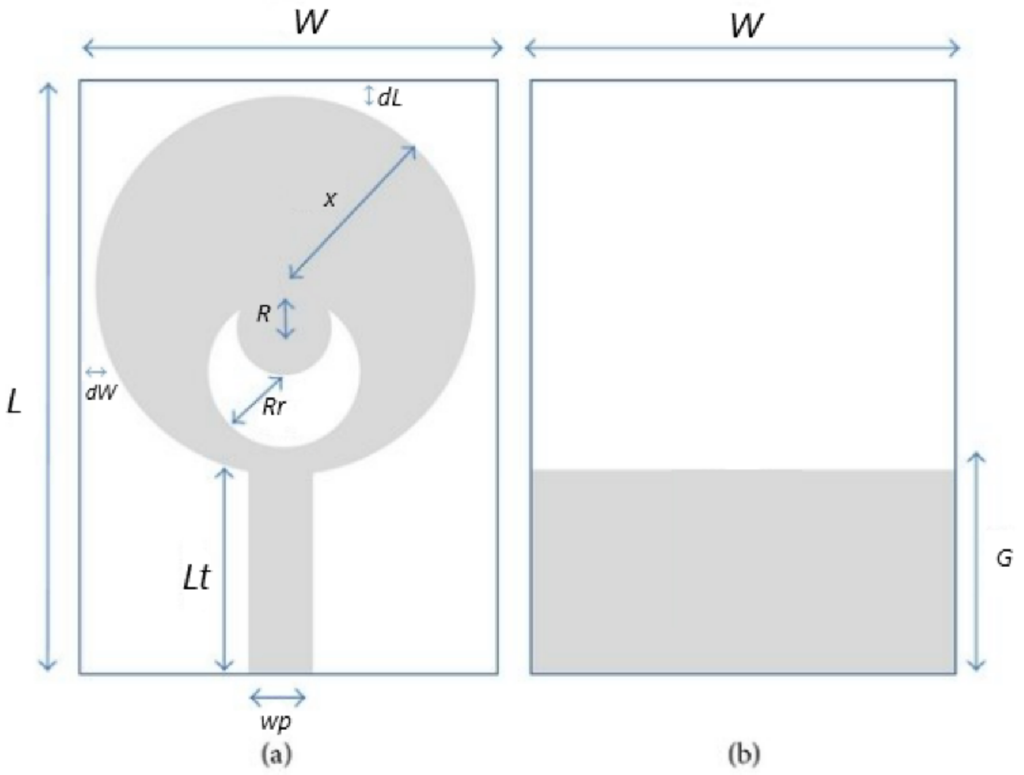
Vojtech Bednarsky

Weekly Report

Process:

- Combining MATLAB – CST MWS
- Choosing Antenna model here
- Problem SETUP
  - Goals: maintain UWB characteristics for certain antenna dimensions
  - Parameter space: *dW, dL, x, Lt, Rr*

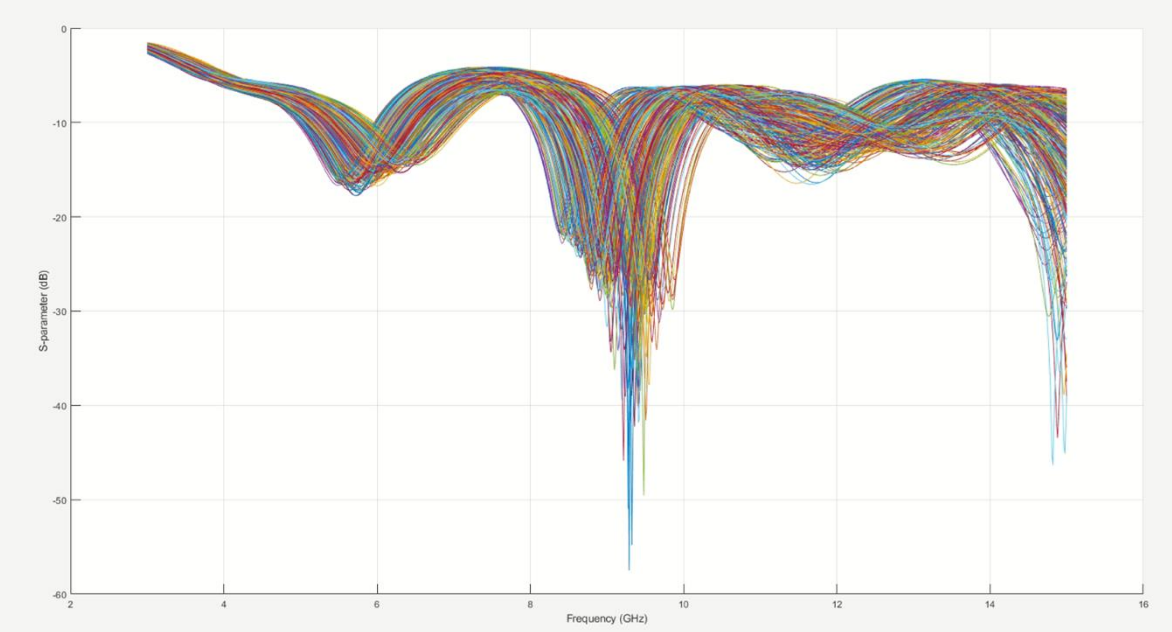
  Note: Other parameters are recalculated through equations.
- Surrogate Model (ANN)
- M.O. (gamultiobj)
  - Frequency Interval Selection
  - Efforts to Improve Design Efficiency
- Verification results with simulation in CST MWS

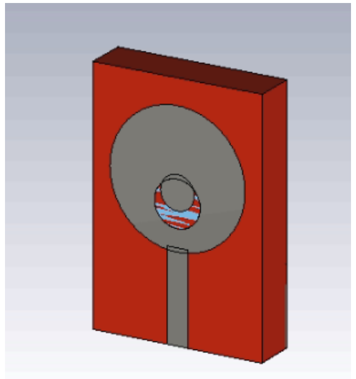


Weekly Report

UWB Antenna Model in CST MWS:

- Acquired Electromagnetic (EM) Data
- Parameter space: +/- **10%** -> *[dW, dL, x, Lt, Rr]*
- For each iteration (row in the file), dimension data *[dW, dL, x, Lt, Rr]* are recorded in columns 1 to 5. Additionally, columns 6 to 2007 contain the values for *S11(real)*, *S11(complex)*.
- Total Iterations (N_samples) = **200**” -> **724** ” for ANN





Weekly Report

Dataset -> ANN

- ANN was trained using dimensions (*x*), *frequency (f), S11(real_data), S11(complex_data)*

Frequency = (3, 3.13, 3.26…15) GHz

f_step: 0.132 GHz

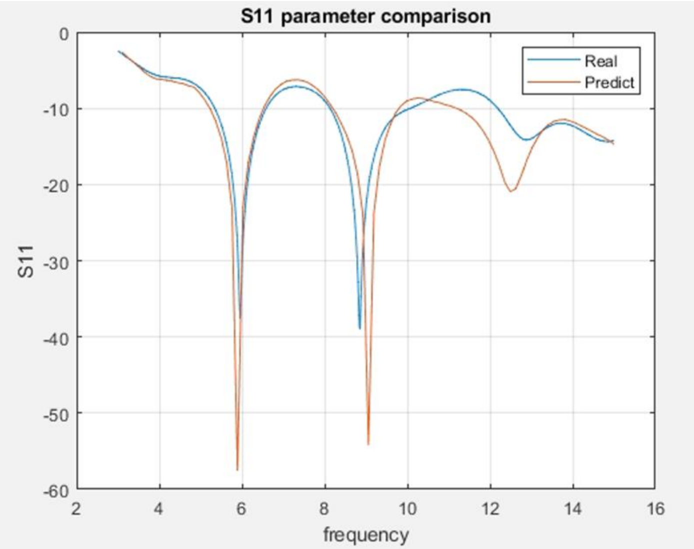
Total Samples = 724s.

Input -> (**x+f**) **….** Output -> **S11(real_data)**

ANN after 200 samples:

MSE(real_data) = 0.045

MSE(complex_data) = 0.085



ANN after 724 samples:

MSE(real_data) = 0.0032

MSE(complex_data) = 0.0055

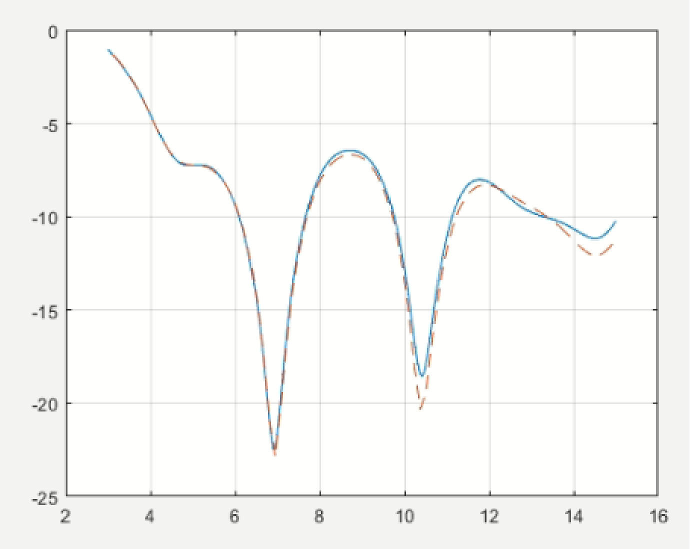
Epoch: 55 iterations

Time: 11 sec.

Performance: 0.00122

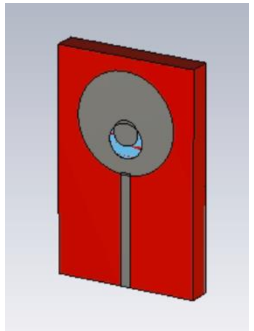
Gradient: 0.000180

Mu: 1.0e-07

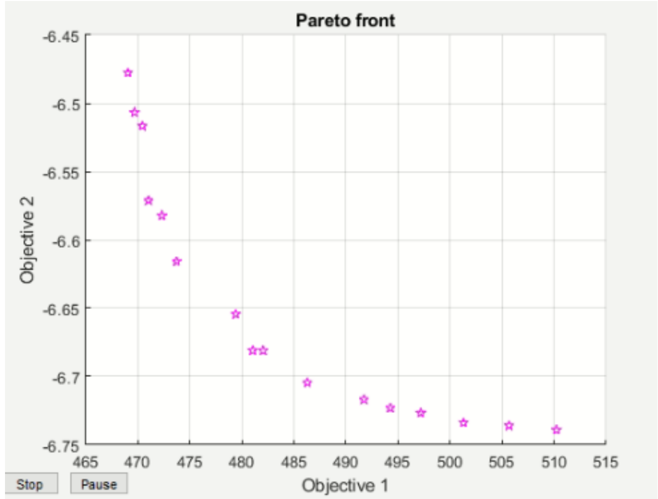


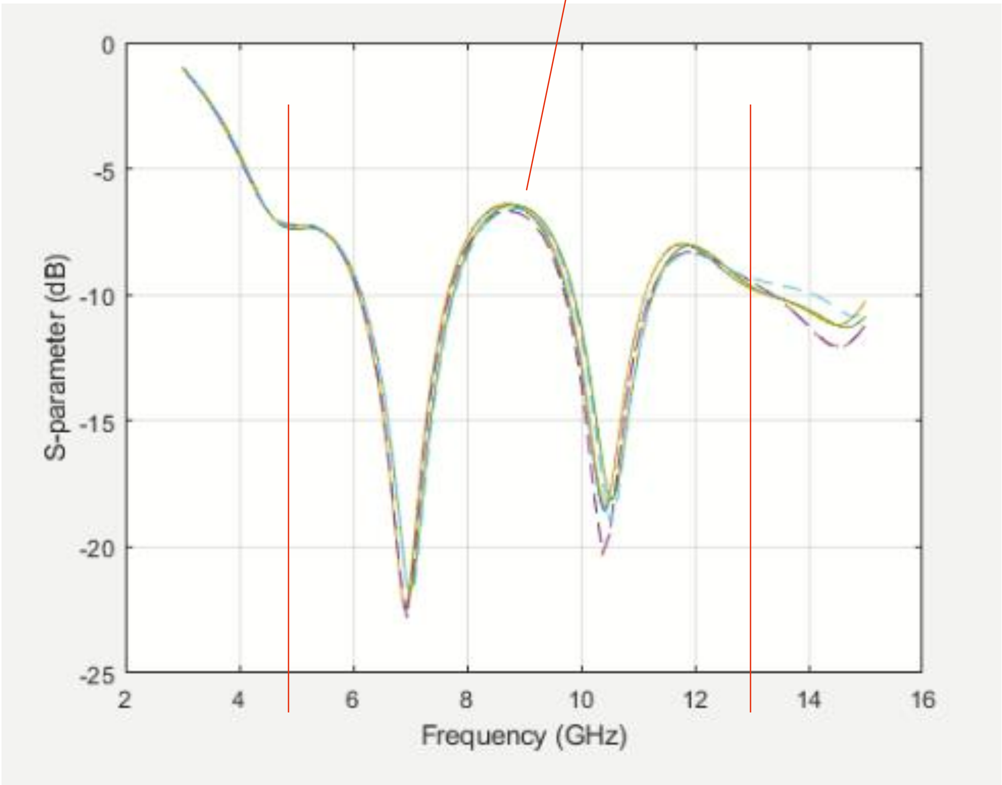
M.O. (gamultiobj)

Selected frequency range = <***5*** ***,13*** > GHz



__ *Data from CST MWS*
--- *Predicted Data from ANN*



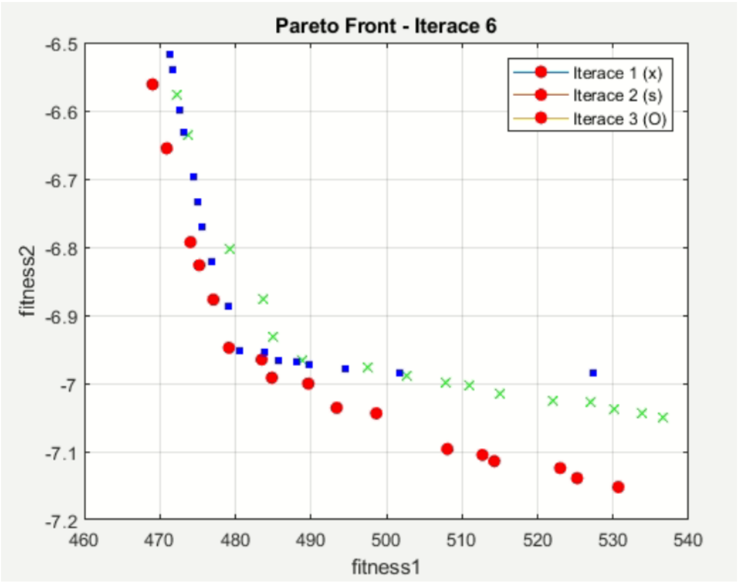


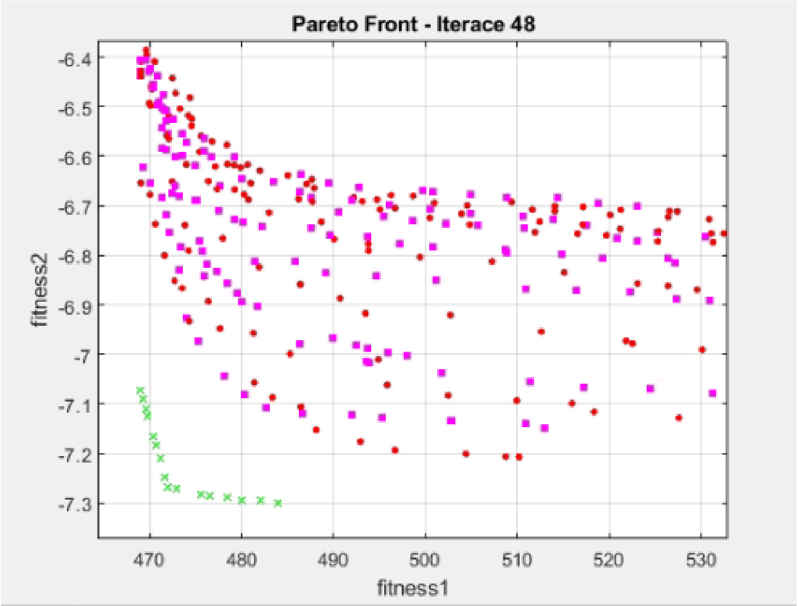
Goals:

- minimized area of the antenna structure
- maintain the broadband characteristic (UWB ANT)

M.O. (gamultiobj)

Selected frequency range = <***5*** , ***13*** > GHz






```
Command Window
Simulation Run Time was 40.4327 seconds.
Porovnání výsledků pro interval design: <3>
M.O.:    max(S11) = -6.4871 dB
CST:     max(S11) = -6.5354 dB
Běží simulace číslo:4/18
Creating new microwave studio session
Simulation Running...
Simulation Finished
Simulation Run Time was 46.4470 seconds.
Porovnání výsledků pro interval design: <4>
M.O.:    max(S11) = -6.7295 dB
CST:     max(S11) = -6.7989 dB
Běží simulace číslo:5/18
Creating new microwave studio session
Simulation Running...
Simulation Finished
Simulation Run Time was 42.6368 seconds.
Porovnání výsledků pro interval design: <5>
M.O.:    max(S11) = -6.6839 dB
CST:     max(S11) = -6.6386 dB
Běží simulace číslo:6/18
Creating new microwave studio session
Simulation Running...
Simulation Finished
Simulation Run Time was 44.2921 seconds.
Porovnání výsledků pro interval design: <6>
M.O.:    max(S11) = -6.7383 dB
CST:     max(S11) = -6.8715 dB
Běží simulace číslo:7/18
Creating new microwave studio session
Simulation Running...
Simulation Finished
Simulation Run Time was 40.4611 seconds.
Porovnání výsledků pro interval design: <7>
M.O.:    max(S11) = -6.6952 dB
CST:     max(S11) = -6.689 dB
Běží simulace číslo:8/18
fx Creating new microwave studio session
```

https://doi.org/10.1155/2016/2829357

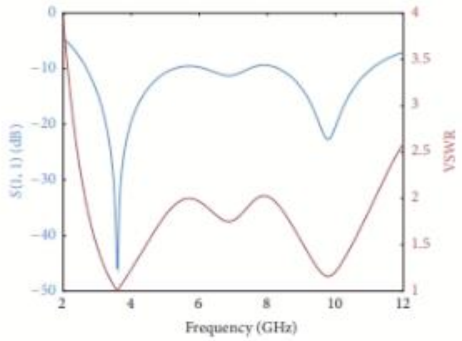
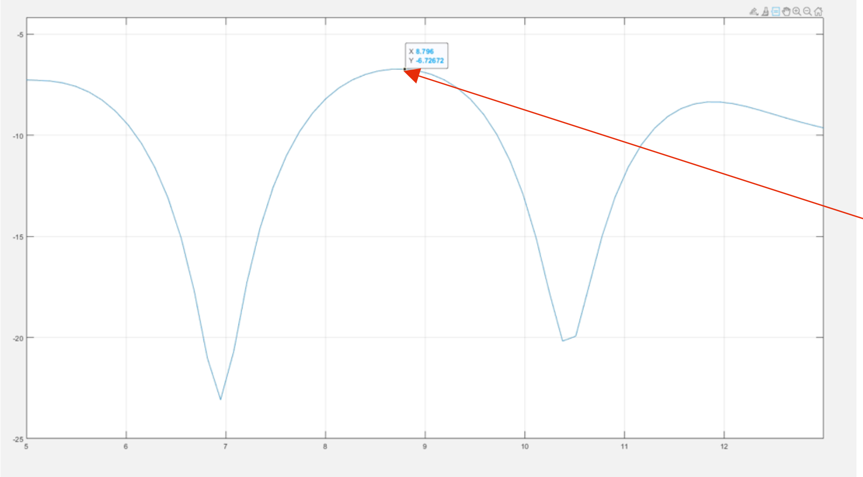


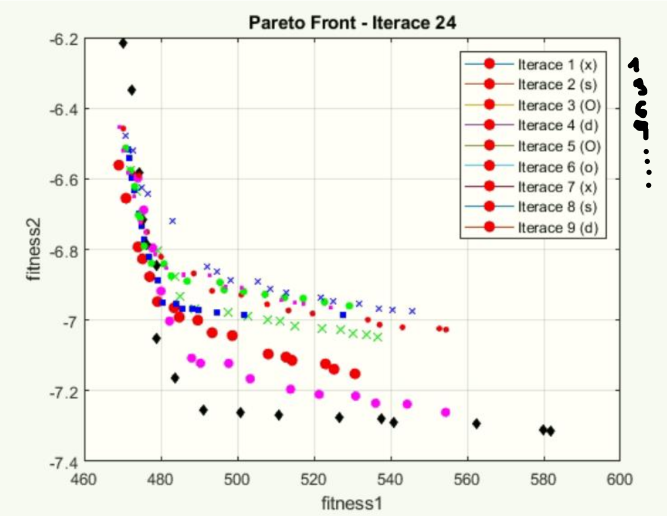
FIGURE 4: Frequency behavior of the UWB monopole antenna input reflection coefficient.



Example:

$_{\Delta}F_4 = |F_4 - F_3|$

$F_N = (F_N, F_{N+1}),\ N \in \langle 1, 3, 6, \dots \rangle$



average_fitness

30x18 double → 18

	1	2	3	4	5	6	7	8
1	0	0	0	0	0	0	0	0
2	0.3682	0.0203	0.0561	0.0868	0.0428	0.1440	0.0164	0.2042
3	0.0346	0.3690	0.2962	0.1083	0.0615	0.1916	0.2049	0.0102
4	0.1028	0.4372	0.2981	0.0785	0.1641	0.2583	0.2349	3.4019e-04
5	0.0743	0.3881	0.0030	0.3719	0.1884	0.0377	0.3387	0.0663
6	0.0133	0.0642	0.0066	0.2311	0.0364	0.3752	0.3269	0.0731
7	0.1177	0.0448	0.0193	0.0968	0.3228	0.3102	0.1702	0.0599
8	0.0616	0.0306	0.0422	0.0576	0.3693	0.0588	0.1677	0.0156
9	0.2130	0.0901	0.2058	0.0934	0.0068	0.0372	0.0137	0.0202
10	0.0955	0.0682	0.1941	0.0054	0.0431	0.1667	0.0811	0.0833
11	0.1140	0.0188	0.1662	0.0024	1.8910e-04	0.1329	0.2410	0.0313
12	0.0361	0.0354	0.0850	0.3374	0.1931	6.1195e-04	0.2199	0.0226
13	0.1078	0.1000	0.1421	0.3562	0.2677	0.2258	0.3194	0.0211
14	1.4138e-04	0.0197	0.3506	0.1039	0.0879	0.3020	0.0911	0.2496

↓ N_MAX (ITER)

MAX (S_{11}) [dB]

val(:,:,2) =

Columns 1 through 17

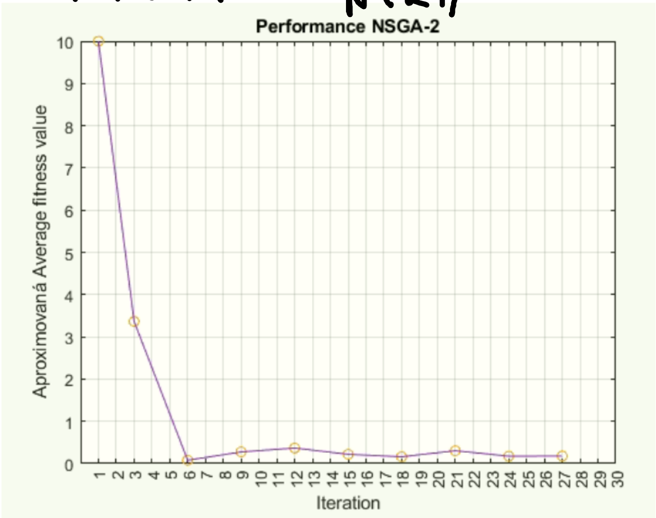
-7.0734	-7.3018	-7.2688	-7.2902	-7.1827	-7.1249	-7.0734	-7.3018	-7.1090	-7.2959	-7.1653	-7.2865	-7.2937	-7.2827	-7.2707	-7.0895	-7.2470
-6.9979	-7.3145	-7.1558	-7.1816	-6.9979	-7.3109	-7.2999	-7.0189	-7.2977	-7.2923	-7.1951	-7.2459	-7.0813	-7.2575	-7.3098	-7.3145	-7.2357
-7.0816	-7.1334	-7.1290	-6.2543	-7.0446	-7.1201	-6.9264	-6.8292	-6.3329	-7.1383	-7.1218	-6.5881	-6.6734	-6.9731	-7.1080	-6.2543	-7.1343
-6.7105	-7.2523	-7.1041	-6.8116	-7.2364	-6.9705	-7.2553	-7.2620	-7.2656	-6.8708	-7.2702	-7.2072	-7.1616	-6.7728	-6.7105	-6.9332	-7.0547
-6.7338	-7.2866	-7.2408	-7.1098	-6.7338	-7.0610	-7.2733	-6.9430	-7.1613	-6.8714	-7.2629	-7.1929	-7.0009	-6.7938	-6.9430	-7.1706	-6.8439
-6.6542	-7.2062	-6.6542	-6.9330	-7.0868	-7.0569	-7.1758	-6.8517	-6.8663	-7.1523	-6.8001	-7.2069	-7.2006	-6.6776	-7.1931	-7.1056	-6.9477
-6.6507	-7.2161	-7.2319	-7.2403	-6.6507	-7.1589	-6.9053	-6.8682	-6.9597	-7.1769	-6.7851	-7.2318	-6.9897	-6.9045	-7.0731	-7.1060	-7.1254
-6.7443	-7.2506	-7.2431	-6.8421	-7.1469	-7.2164	-7.1285	-6.9533	-7.1783	-7.2506	-6.8489	-7.2446	-6.7443	-7.0109	-7.2283	-7.1723	-7.2384
-6.6219	-6.6845	-6.8174	-6.9951	-6.9805	-6.9871	-6.9020	-6.8948	-6.7545	-6.7188	-6.7922	-6.8761	-6.7820	-6.6553	-6.9664	-6.8315	-6.8567
-6.3627	-6.8834	-6.3627	-6.8220	-6.7396	-7.0678	-6.9516	-6.4451	-7.1428	-6.6176	-6.9846	-6.5221	-7.1430	-7.0824	-6.3630	-7.1271	-7.1728
-6.4860	-7.2453	-7.2271	-6.4860	-6.9530	-6.5470	-7.1860	-7.2259	-7.2083	-6.8592	-7.1497	-6.6582	-6.7495	-7.0533	-7.2373	-6.9720	-7.2241
-6.4929	-6.8930	-7.0932	-6.6513	-7.0613	-7.0988	-7.1158	-6.9572	-6.7391	-7.1342	-6.9991	-7.0828	-6.8431	-7.1280	-7.0103	-6.5651	-6.4929

→ 18

↓ N_MAX (ITER)

$N \in \langle 1, 3, 6 \dots \rangle$

$\text{MEAN}\,(_{\Delta}F_{N(1)} - {_{\Delta}F_{N(2)}})$



DIM. [MM^2]

fitness_history

50x18x2 double

val(:,:,1) =

Columns 1 through 17

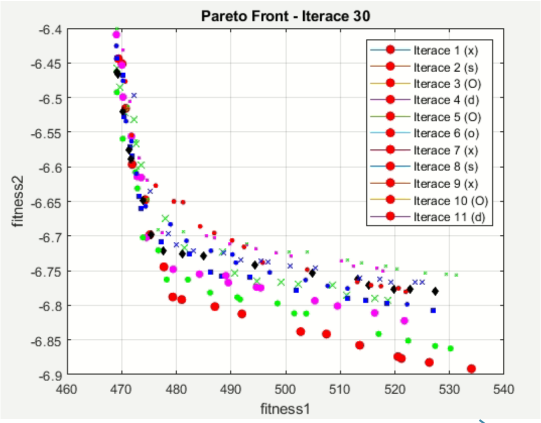
469.0334	483.9298	471.9872	478.3602	470.6469	469.7453	469.0334	483.9298	469.5482	482.0741	470.3323	476.4566	480.0519	475.5978	472.9321	469.3118	471.6428
469.0334	486.0244	471.3109	471.7706	469.0334	485.3192	482.1441	469.5474	479.7040	478.1846	472.4913	473.2044	470.3250	475.5979	483.2142	486.0244	472.7091
480.3145	502.6507	495.2370	469.0334	478.1485	486.6114	474.0576	473.1985	470.1536	510.9032	492.0044	471.8595	472.4340	475.2222	482.6751	469.0334	502.8370
469.0334	491.5604	478.2959	471.0543	488.4545	473.3606	497.6506	503.1174	504.4253	471.6314	510.4409	482.8185	480.5579	469.9457	469.0334	472.7779	476.6529
469.0334	491.2998	481.6297	474.9734	469.0334	474.6673	486.7506	472.3004	476.0095	471.3834	483.7238	477.5878	473.5089	469.8911	472.3004	476.7993	470.6612
469.0334	508.7176	469.0334	474.3003	483.3592	481.3628	492.9237	472.6975	473.5183	488.0990	471.6183	510.1656	504.3694	470.0366	496.6810	486.4270	477.6320
469.0334	486.2945	491.1797	493.6274	469.0334	482.3170	473.5359	472.4697	474.0730	484.3459	470.8985	488.6666	474.4959	473.1788	476.4162	478.5927	479.9791
469.0334	503.8645	495.3754	470.5404	477.5664	488.0030	476.0310	472.3292	481.1462	503.8645	471.2825	502.6070	469.0334	473.5787	489.5021	480.4187	493.5237
469.2858	471.2664	476.1648	495.9189	492.3927	493.7702	481.6565	479.9513	472.0670	471.7490	475.6912	479.5447	473.3736	470.0148	489.9258	477.2616	478.3858
469.0334	488.8641	469.0334	484.1918	480.7290	514.1164	496.2143	471.7725	532.9578	475.2941	499.6280	475.1797	540.5483	517.8815	469.0410	530.1963	542.1490
469.5731	533.9175	520.5286	469.5731	477.5520	470.6920	494.8993	520.1884	504.5344	475.8994	491.1872	472.5613	474.0549	485.3012	528.4860	481.3158	512.2227
469.9538	476.3775	509.8986	472.4485	495.8152	515.9228	518.3245	481.2767	473.8228	537.8384	485.2562	502.4585	475.8565	527.5361	494.8495	472.0635	469.9538

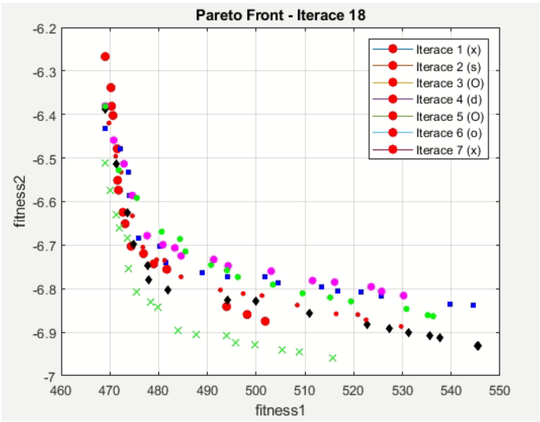
→ 18

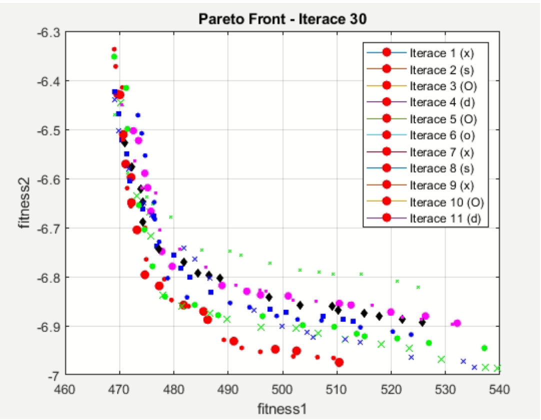
↓ N_MAX

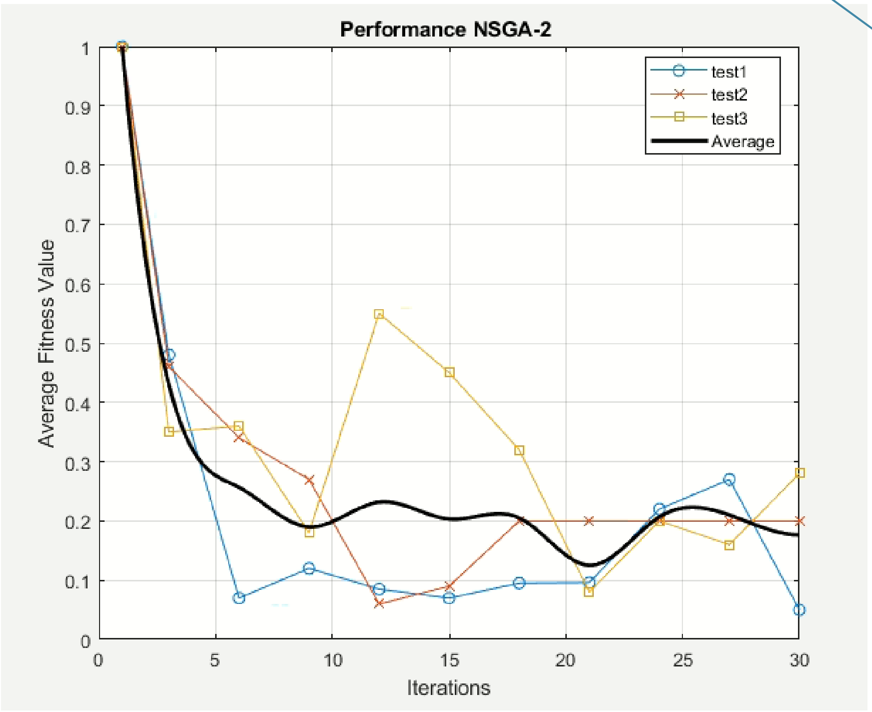
If 3 consecutive mean $\Delta(F_{iteration})$ < *treshold* => stop optimization

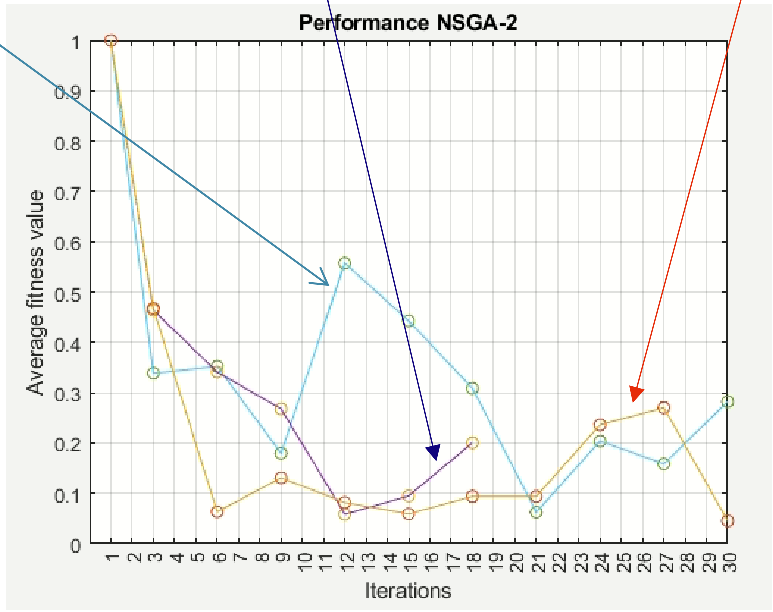
Example:











Command Window

```
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Porovnání výsledků pro interval design: <3>
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M.O.:    max(S11) = -6.6952 dB
CST:     max(S11) = -6.689 dB
Běží simulace číslo:8/18
fx Creating new microwave studio session
```

M.O. (gamultiobj)

Main part of the code

```
% Určete počet iterací, po kterých chcete provádět průměrování
prumerovaciInterval = 3;
iteraceProPrumerovani = 3;

for iterace = 1:maxPocet
    disp(['Běží iterace číslo:', num2str(iterace),', celkem už provedeno simulací:', num2str(c_simulaci)]);
    [x, fval] = f_NSGA2(nvars, f, Net_imag, Net_real, lb, ub, intervalStart, intervalEnd,iterace,treshold);

    if iterace > 1
       average_fitness(iterace,:) = (abs(fval(:, 2) - fitness_history(:, 2)))';
       average_fitness_history(iterace) = mean(average_fitness(iterace));

        % Porovnejte fitness hodnoty s předchozí generací z historie
        if average_fitness_history(iterace) < convergence_threshold
           consecutive_generations = consecutive_generations + 1;
        else
            consecutive_generations = 0;
        end
    else
        average_fitness(iterace,:) = zeros(1, 18);
        average_fitness_history(iterace) = 1;
    end

    if consecutive_generations >= max_consecutive_generations
        % Dosáhli jsme konvergence, ukončeme optimalizaci
        disp(['Convergence achieved!!']);
        break;
    end

    % Uložte aktuální hodnoty fitness do historie
    fitness_history(:, :) = fval;
```

M.O. (function – evaluate_fitness_function)

```
function [fitness] = f_evaluate_fitness_function(Net_real, Net_imag, design, f, intervalStart, intervalEnd, treshold)

    % Simulace antény
    S11_dB = [];
    f1 = []; % Inicializace pole pro začátky intervalů
    f2 = []; % Inicializace pole pro konce intervalů
    [S11_dB] = f_simulate_antenna(Net_real, Net_imag, design, f);
    fitness = [1e6, 1e6];

    % První kritérium - minimalizace tvaru antény
    ub_Rr = 0.35 * design(3);
    lb_Rr = 0.3 * design(3);
    design(5) = unifrnd(lb_Rr, ub_Rr);
    fitness(1) = f_calculate_shape(design(1), design(2), design(3), design(4), design(5));

    %Druhé kritérium - search max S11 na hledaném frekvenčním pásmu

    % Najděte indexy hodnot, které jsou v daném intervalu
    indicesInInterval = find(f >= intervalStart & f <= intervalEnd);
    fitness(2) =  max(S11_dB(indicesInInterval));
end
```

M.O. (function – calculate_shape)

```
function antennaShape = f_calculate_shape(dW, dL, x, Lt, Rr)
    % Výpočet šířky a délky antény
    w = 2 * dW + 2 * x;
    l = Lt + 2 * x + dL;

    % Výpočet plochy antény s penalizací na základě Rr
    area = (w * l);

    % Výsledek v mm2
    antennaShape = area;
end
```

More promising antenna designs:

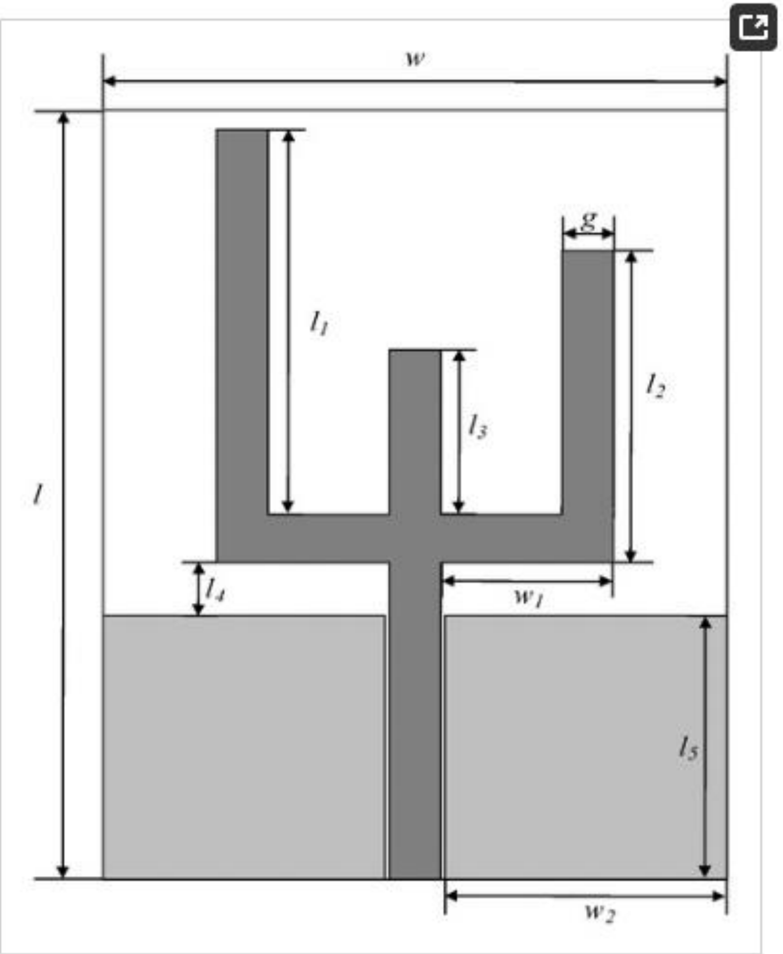
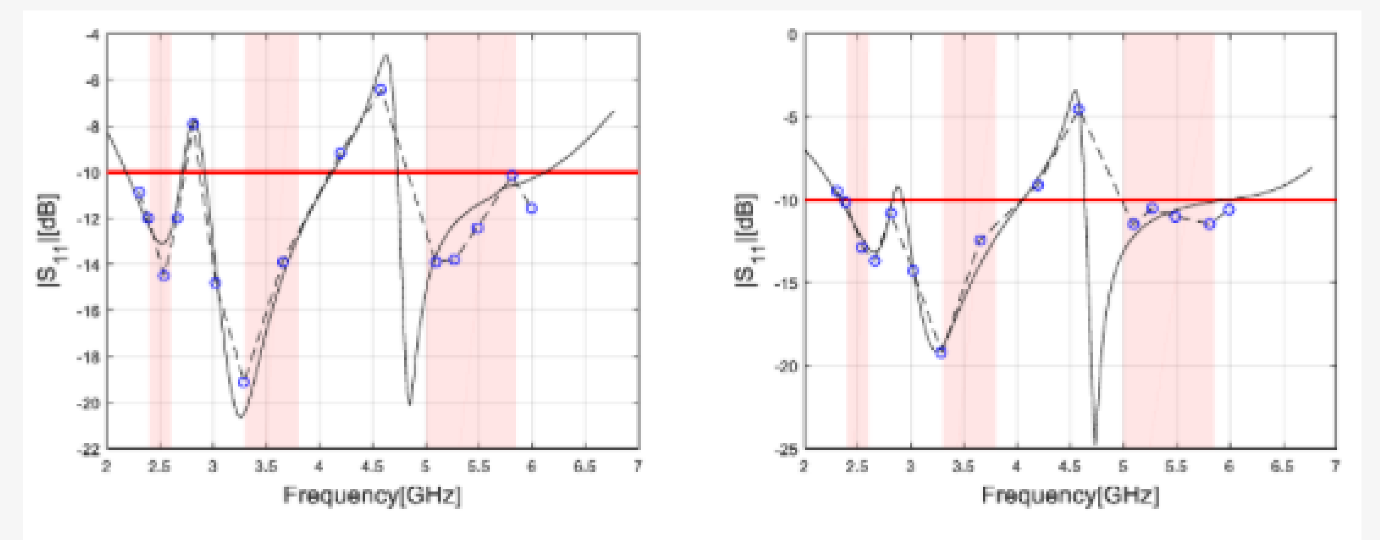


Figure 8. Geometry of the planar multiband antenna.

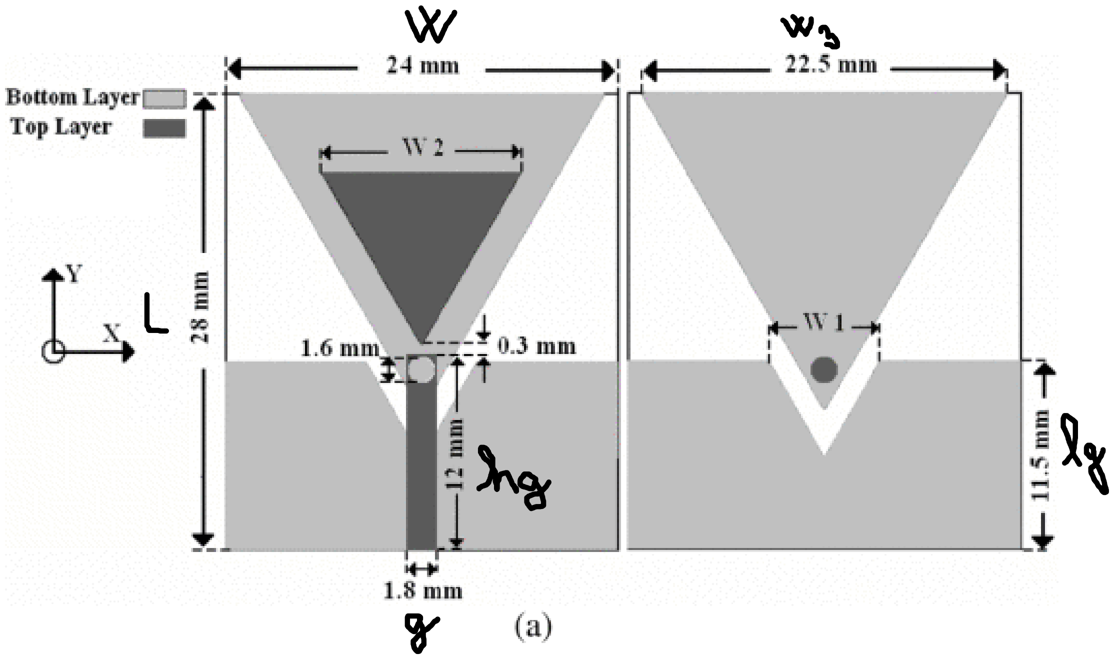
$\mathbf{x}$=[$l\ l1\ l2\ l3 l4\ l5\ w\ w1 w2\ g$]^T

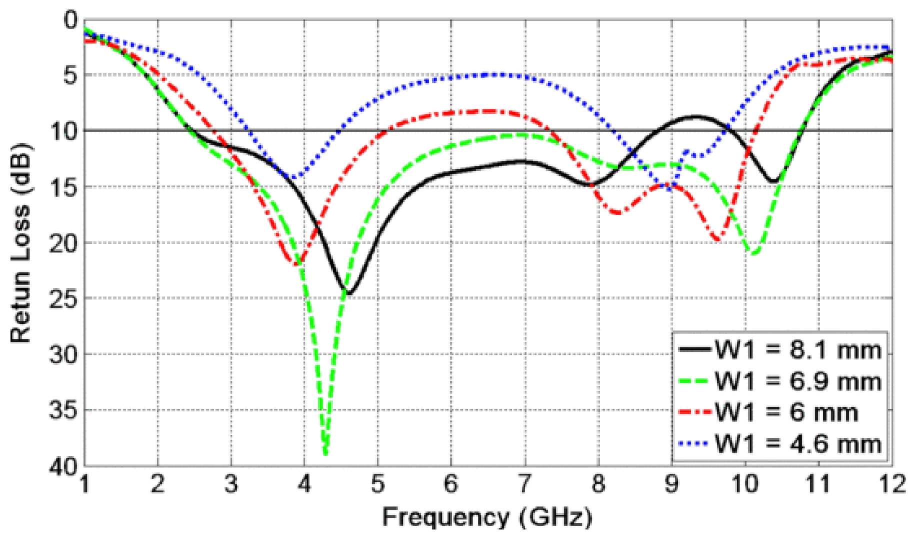


Link: HERE

More promising antenna designs:

$\mathbf{x}$=[$W\ L\ W1\ W2\ W3\ lg\ g\ hg$]^T





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More promising antenna designs:

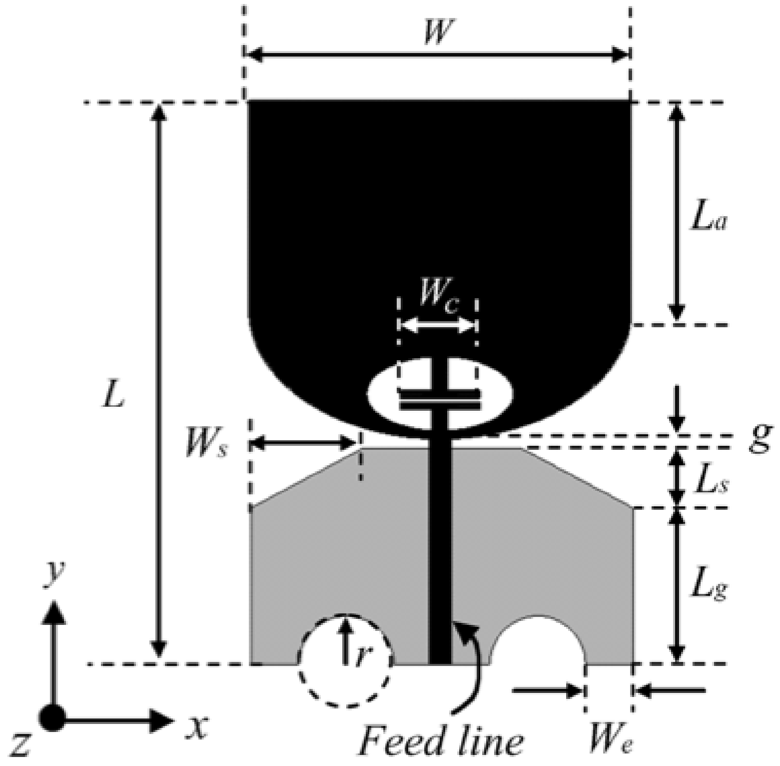
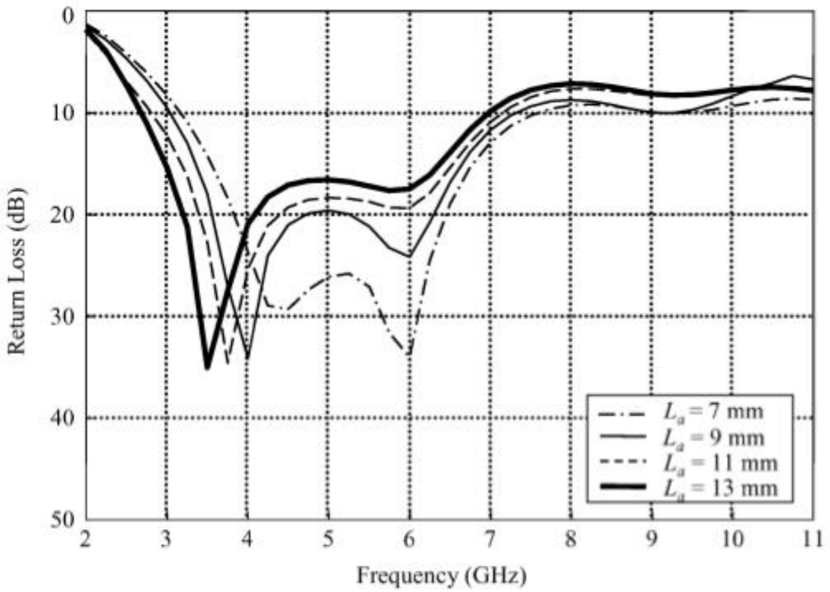


Fig. 1. Geometry of the proposed antenna. $W \times L = 24$ mm $\times$ 35 mm, $L_a =$ 13 mm, $g = 0.6$ mm, $L_g = 9.7$, $W_s \times L_s = 7$ mm $\times$ 3.7 mm, $W_c = 3.6$ mm, $W_e = 3$ mm, $r = 3$ mm.

$\mathbf{x}$=[$W\ l\ la\ lg\ g\ Ws\ Wc\ We\ r$]^T



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