A miniaturization technique for a 1.57542-GHz GPS patch antenna

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Introduction

- Rogers® 4000 series microstrip.
- $\varepsilon_r = 3.38 + j\ 0.0027$.
- A typical micro-strip patch antenna is half a guided wavelength long.
- Effect of di-electric is to shorten the wavelength.

Rationale of the miniaturisation technique

- A microstrip patch is an unbalanced transmission line.
- A transmission line shorter than ¼ the applied signal wavelength exhibits a capacitive input impedance by the input impedance equation.
- The capacitance can be negated by the inductance caused by transverse slots. The inductance is determined by the equation presented by Wolfgang J.R. Hoefer in the IEEE ‘Transactions on microwave theory and techniques. MTT-25: № 10’.

Some maths

$$Zin := Z_L + \frac{Zc(Z_L + jZc(\tan\beta la))}{(Zc + jZ_L\ (\tan\beta la))}$$

Hoefer equation

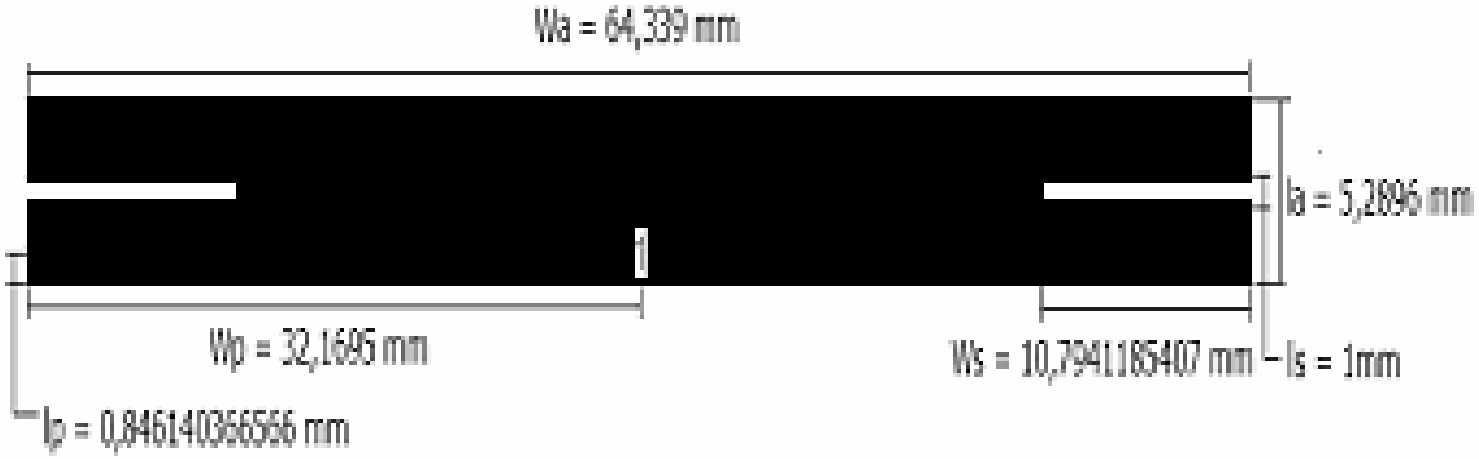
$$Ls := \frac{\mu_{\circ} \cdot h \cdot \Pi}{4} \left(2 \frac{Ws}{Wa} \right)^2$$

More of the rationale of the miniaturisation technique

- The shorter the patch, the less capacitive it is.
- The miniaturised micro-strip patch antenna (MMPA) at one twentieth of the guided wavelength (λg/20) long = 5.2896 mm @ 1.57542 GHz.

Transverse inductive slot geometry

- Transverse inductive slots (TIS) are placed in the y-axis of the conducting plane of the rectangular patch antenna to counteract the capacitive reactance of the shortened antenna.



Electrical equivalent circuit

- The net electrical result being a capacitance in series with an inductance in series with a capacitance, resonating at 1.57542 GHz.

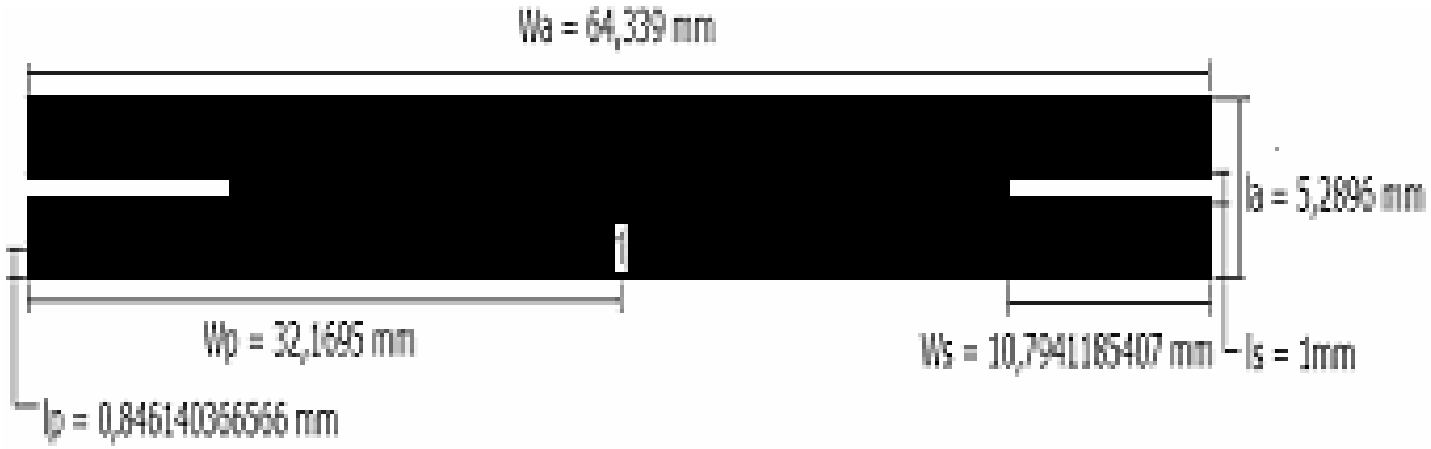
Challenges

- Available design equations are equitable to the dimensions obtained by manual optimisation.
- Probe placement equations are not accurate.
- Probe placement has an effect on the reactive component of the input impedance.

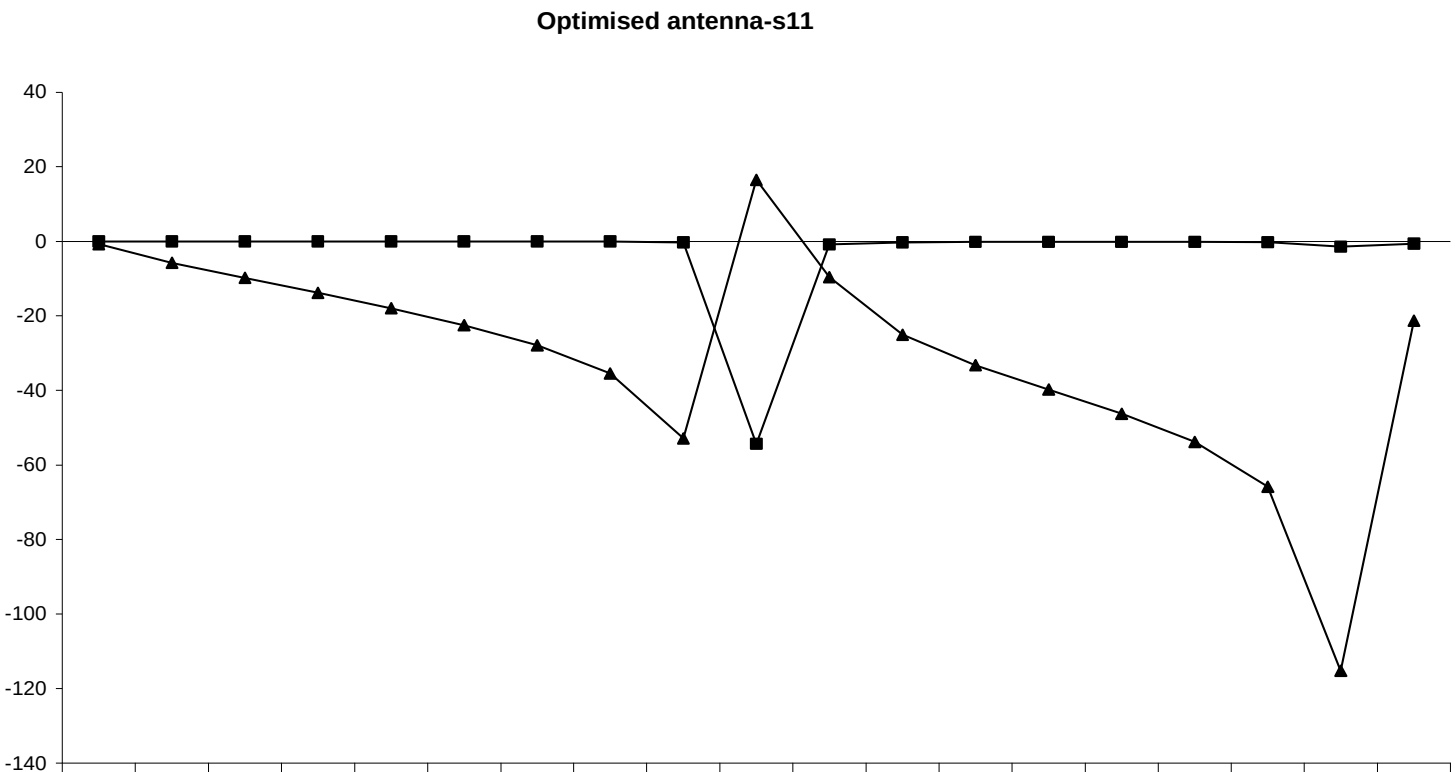
MMPA Simulation results

- A probe-fed 5.2896 mm patch was simulated first.
- Patch length further reduced to 5 mm and the slot width (Ws) reduced to 3 decimal places for manufacturing simplicity and accuracy.
- A 5 mm ¼ transformer fed model was simulated to eliminate probe footprint reaction.
- The return loss (s_{11}) result is presented for each simulation.

λg/20 Probe fed patch (la=5.2896 mm)

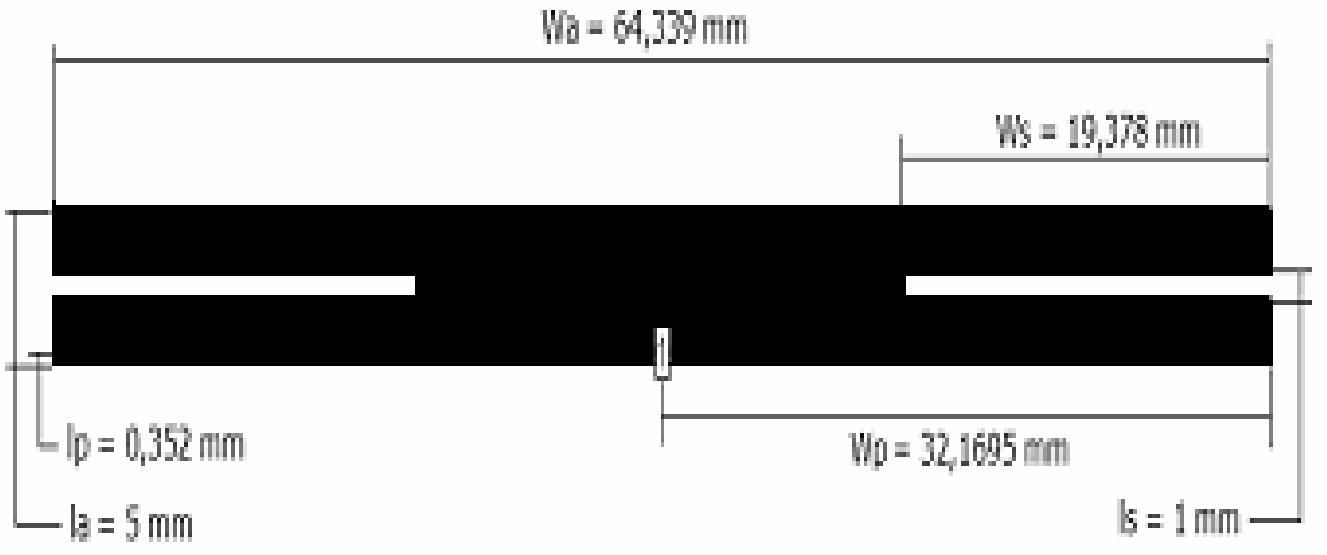


s_{11} characteristic of 5.2896 mm patch

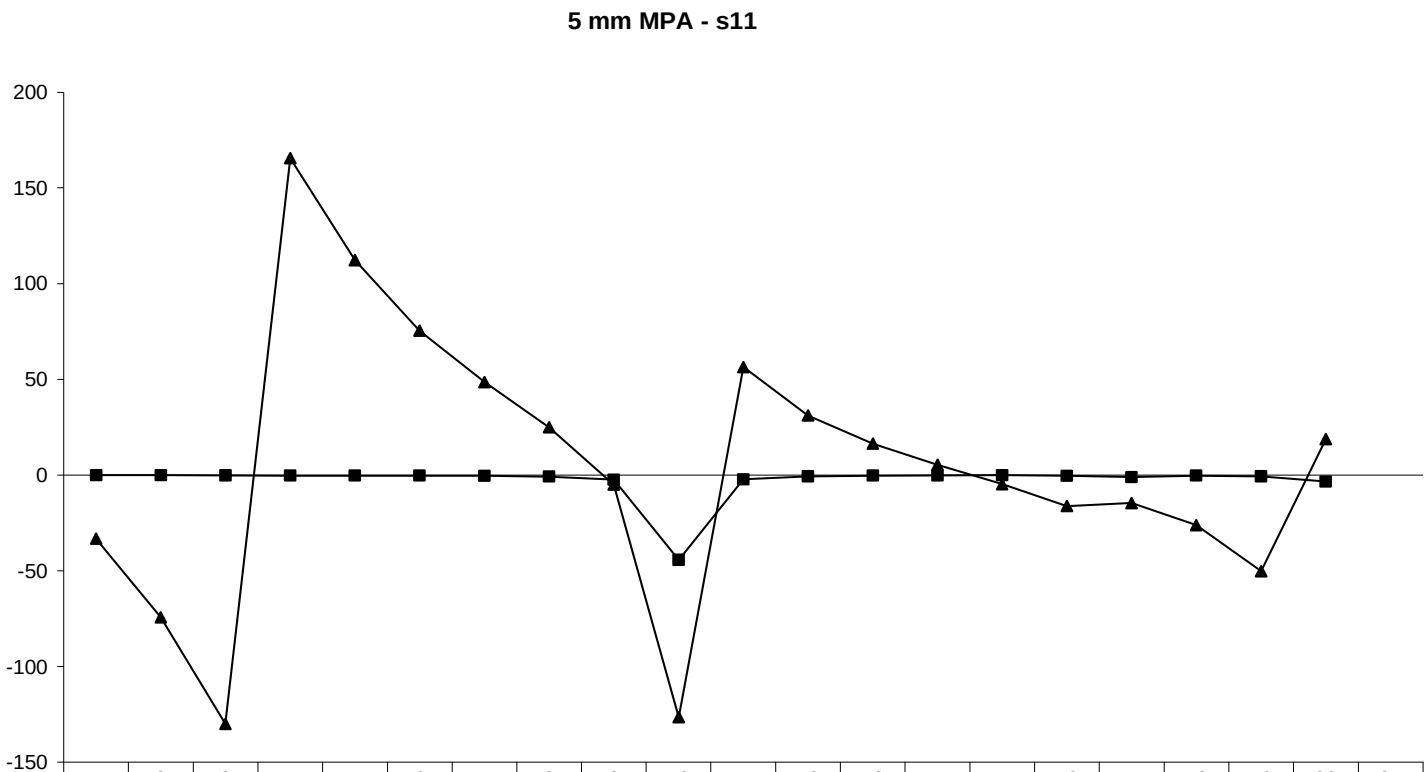


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Frequency	0.1575	0.3151	0.4726	0.6302	0.7877	0.9453	1.103	1.26	1.418	1.5754	1.733	1.891	2.048	2.206	2.363	2.521	2.678	2.836	2.993
dB	-0.014	-0.007	-0.007	-0.008	-0.011	-0.016	-0.026	-0.055	-0.263	-54.37	-0.842	-0.292	-0.186	-0.154	-0.148	-0.163	-0.237	-1.433	-0.651
Phase	-0.735	-5.747	-9.818	-13.81	-17.97	-22.52	-27.93	-35.47	-52.85	16.48	-9.579	-25.03	-33.22	-39.79	-46.25	-53.82	-65.83	-115.2	-21.29

5 mm probe fed patch

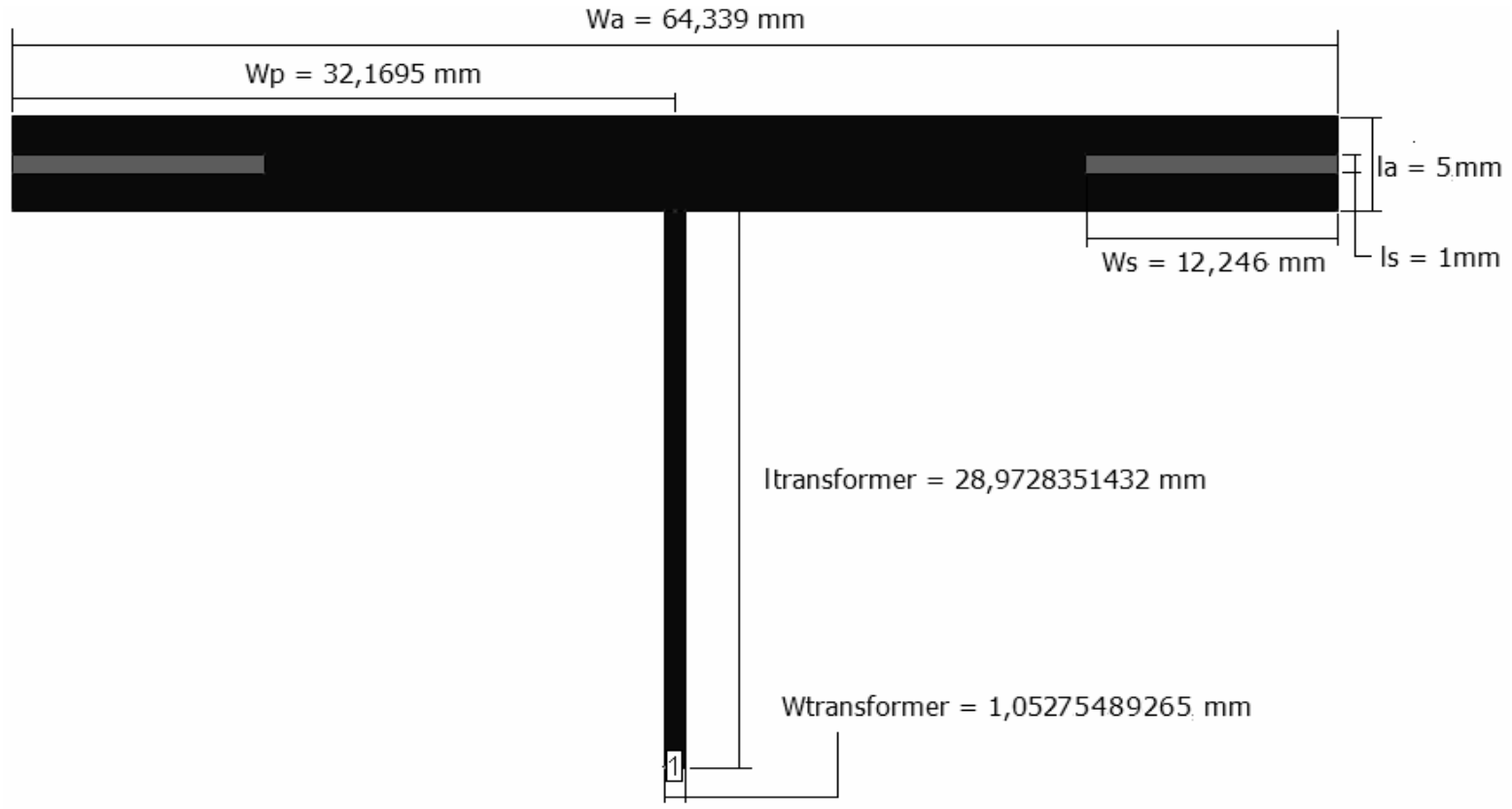


s_{11} characteristic of 5 mm patch

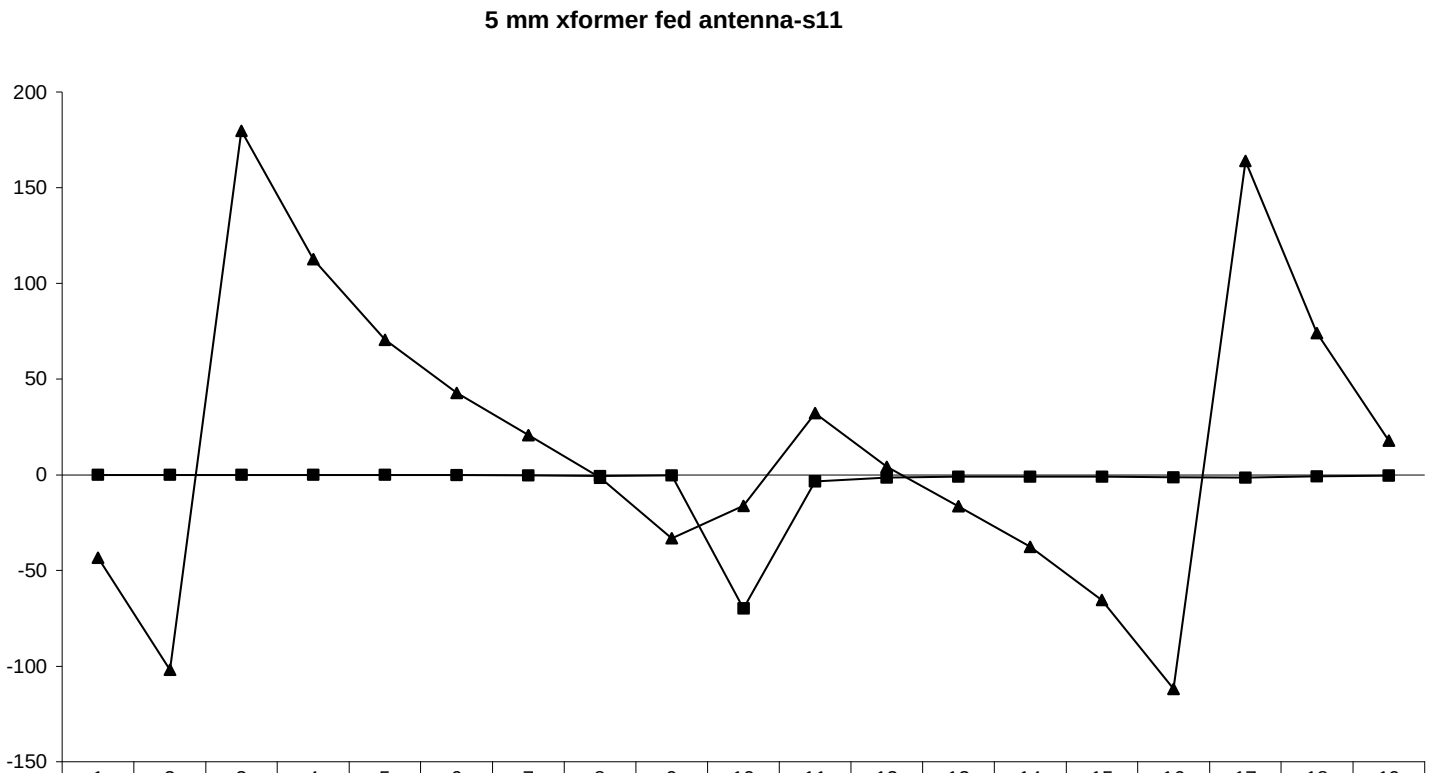


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Frequency	0.158	0.315	0.473	0.63	0.788	0.945	1.103	1.26	1.418	1.575	1.733	1.891	2.048	2.206	2.363	2.521	2.678	2.836	2.993		
dB	-0.02	-0.08	-0.19	-0.29	-0.31	-0.32	-0.42	-0.77	-2.36	-44.3	-2.3	-0.66	-0.28	-0.13	-0.09	-0.43	-1.12	-0.3	-0.69	-3.46	
Phase	-33.3	-74.3	-130	165.5	112.3	75.46	48.63	24.97	-5.03	-127	56.54	31.05	16.4	5.324	-4.71	-16.1	-14.6	-26.2	-50.3	18.73	

5 mm λg/4 transformer fed patch

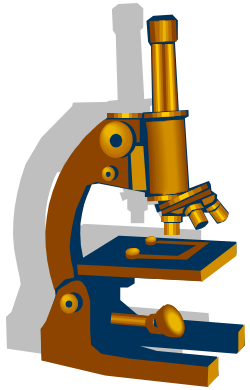


s_{11} characteristic 5 mm λg/4 transformer fed patch



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Frequency	0.1575	0.3151	0.4726	0.6302	0.7877	0.9453	1.103	1.26	1.418	1.5754	1.733	1.891	2.048	2.206	2.363	2.521	2.678	2.836	2.993
dB	-0.016	-0.048	-0.082	-0.084	-0.093	-0.136	-0.256	-0.634	-0.244	-69.78	-3.456	-1.496	-1.014	-0.905	-1.012	-1.365	-1.548	-0.799	-0.449
Phase	-43.31	-101.9	179.7	112.6	70.52	42.75	20.75	-1.42	-33.22	-16.26	32.11	4.176	-16.49	-37.69	-65.54	-111.9	164	74.04	17.79

5 mm transformer fed patch -Physical test result-



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