EDGES MEMO #334

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To: EDGES Group

From: Alan E.E. Rogers

Subject: Circuit model simulation of EDGES data

A circuit model of the EDGES LNA is shown in Figure 3 of memo 62. The noise model of the circuit was partially analyzed in 2010 with early EDGES software but was not used for a complete simulation of the calibration and analysis. Finally, after 10 years of occasional thoughts of using the circuit model the generate a complete simulations, I have added the input attenuator to the circuit noise model and written spectral and S11 data without using any noise wave or S parameter equations. Apart from linear circuit analysis the only physics I have used is the assumption that the thermal noise voltage is proportional to the square root of the resistance and the noise power is proportional to temperature.

The circuit model in memo 62 was developed before the development of the noise wave model in memo 76. Some minor improvements in the LNA circuit were made in memo 102. The addition of the 3 dB attenuator and some minor additional circuit changes were reported in memos 164 and 165. Tests of the temperature sensitivity and a photo of the PC board are shown in memo 218. Memo 300 shows the LNA circuit used in EDGES-3. Some minor circuit changes which include the inductance on the input and the bias adjustment resistor exist in individual LNAs. These adjustments have been made to obtain the best input S11 during checkout. The c-code used for the simulations in this memo used the latest updates in most cases although I am still checking on this assumption.

The parameters for the ATF-54143 came from the original Agilent P-HEMT data sheet. While the actual circuit model values are a combination of the transistor and PC board inductance and capacitance along with the other components. The basic model in Figure 3 of memo 62 which shows most components as resistors are complex impedances made up of a combination of resistance, inductance and capacitance.

Table 1 gives some key circuit parameters. The basic model in Figure 3 of memo 62 but each of the components shown as a resistor are complex impedances made up of a combination of resistors, capacitors and inductors.

item	symbol in c-code	value
FET transconductance	gin	0.41 S
Feedback resistance resonant frequency	reson	1 GHz
Feedback resistance	rrf	910 ohms
FET gate - drain	c	0.31 pf
FET delay	tau	12 ps
Source inductance	L	0.7e-9
Source resistance	Rs	1 ohm
FET gate – source	cg	1.73 pf

Table 1 Some key parameters

Figure 1 shows the results of the calibration using spectra generated for a sky model with spectral index -2.5 and 300 K at 150 MHz along with spectra for the ambient, hot load, open and shorted cables. The S11 data for the LNA with 3 dB attenuator on the input comes from the circuit model. The S11 for the antenna comes from a FEKO simulation of EDGES-3 and the S11 for the ambient, hot, open and shorted cables come from cable models. In all cases the noise model is used to generate the "antenna, load, load +cal, spectra" for the 3 position switch cycle in each case.

In summary this test simulation is another test of the validity of the formulas based on amplifier "noise waves" used in the EDGES analysis based on

Meys, R. P. "A wave approach to the noise properties of linear microwave devices." *IEEE Transactions on Microwave Theory and Techniques* 26, no. 1 (1978): 34-37.

Figure 2 is a copy of the ATF-54143 die model

It is noted that the LNA S11 and the LNA noise waves extracted from the spectral data generated from the circuit noise model are close to those of real EDGES-3 data. It is also noted that the calibrated spectrum of the sky model is within about 5 mK of the assumed sky model.

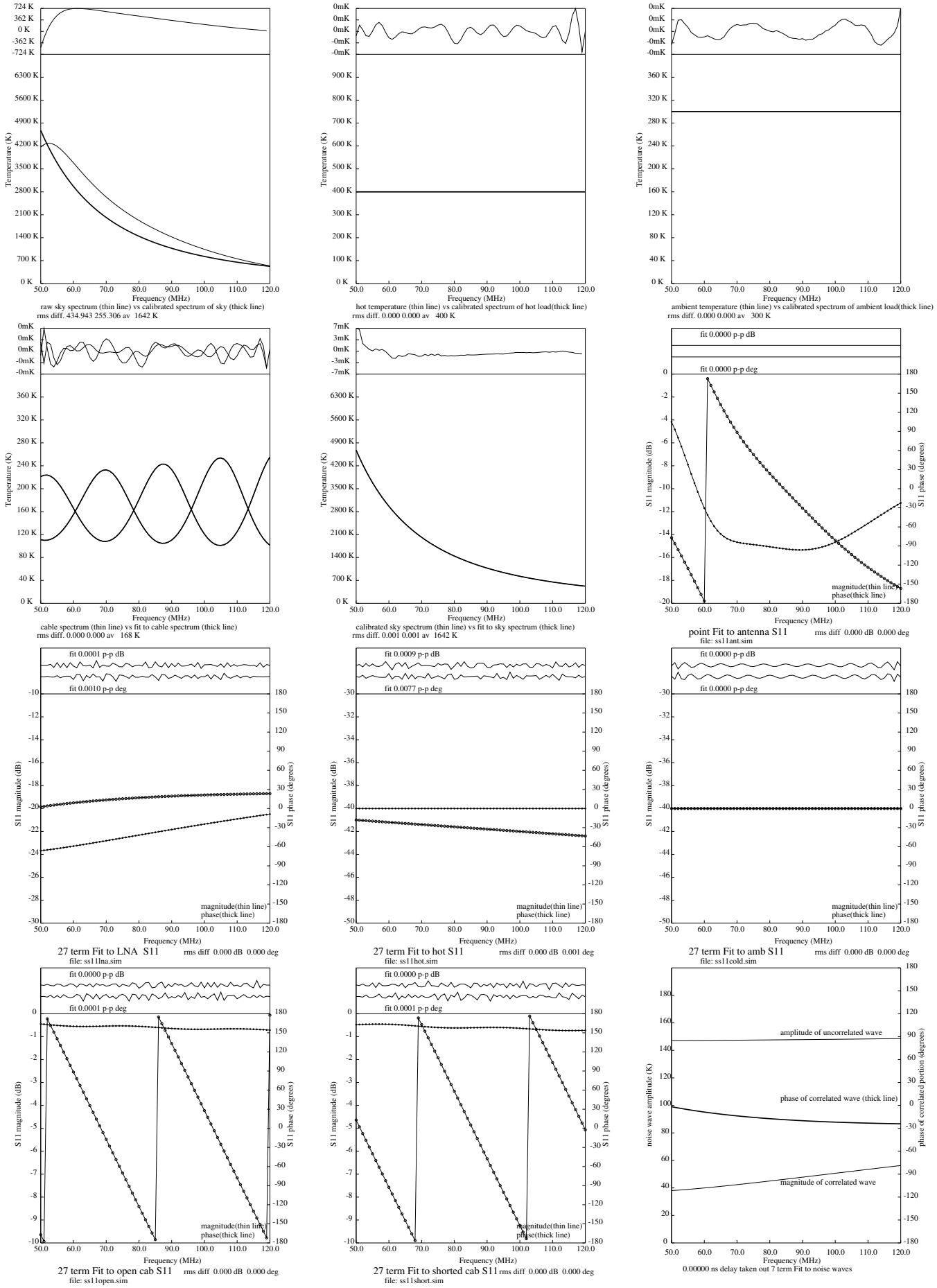
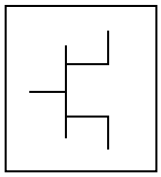


Figure 1. The results of the circuit noise model simulation of spectra and S11 data processed with EDGES software based on noise wave analysis.

ATF-54143 Die Model



Advanced_Curtice2_Model
MESFETM1

NFET=yes	Rf=	Crf=0.1 F	N=
PFET=no	Gscap=2	Gsfwd=	Fnc=1 MHz
Vto=0.3	Cgs=1.73 pF	Gsrev=	R=0.08
Beta=0.9	Cgd=0.255 pF	Gdfwd=	P=0.2
Lambda=82e-3	Gdcap=2	Gdrev=	C=0.1
Alpha=13	Fc=0.65	R1=	Taumdl=no
Tau=	Rgd=0.25 Ohm	R2=	wVgfwd=
Tnom=16.85	Rd=1.0125 Ohm	Vbi=0.8	wBvgs=
Idstc=	Rg=1.0 Ohm	Vbr=	wBvgd=
Ucrit=-0.72	Rs=0.3375 Ohm	Vjr=	wBvds=
Vgexp=1.91	Ld=	Is=	wIdsmax=
Gamds=1e-4	Lg=0.18 nH	Ir=	wPmax=
Vtotc=	Ls=	Imax=	AllParams=
Betatce=	Cds=0.27 pF	Xti=	
Rgs=0.25 Ohm	Rc=250 Ohm	Eg=	

ATF-54143 curtice ADS Model

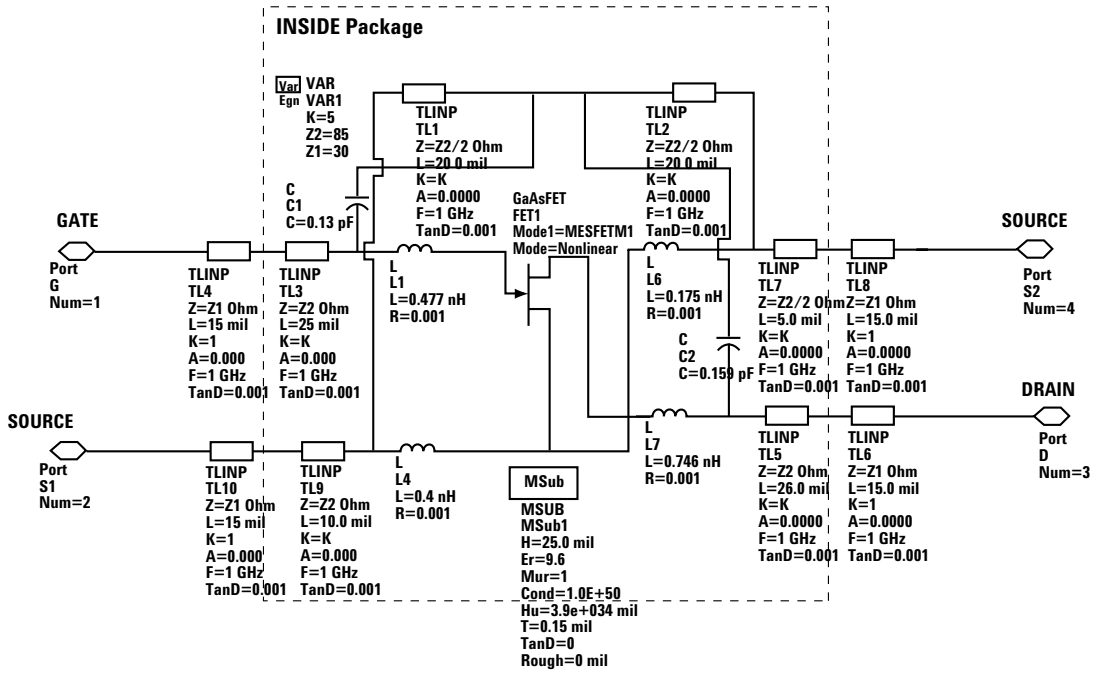


Figure 2. Copy of page 12 of original Agilent datasheet for ATF-54143 P-HEMT