

**Analysis of the frequency dependent complex
magnetic susceptibility of soil samples from test sites
in Bosnia and Herzegovina, Mozambique and Laos**

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A great number of soil samples from several test sites for landmine detection had been delivered by Mr. D. Guelle from the JRC Ispra in September 2005. The assignment was to measure the frequency dependent magnetic susceptibility over a wide frequency range from soils which show this phenomenon due to preliminary measurements. These frequency dependence magnetic soils often cause problems when tracking landmines with metal detectors. The samples from Bosnia and Herzegovina and from Laos were grab samples in 10-ml-capsules and those from Mozambique were composite samples.

Performance of measurements:

The grab samples were directly used for the measurements and the composite samples were homogenised and filled into 10-ml-capsules. The real and imaginary part of the susceptibility at 12 and accordingly 13 different frequencies (50 Hz - 10 kHz) was determined with a Magnon MS 200 kappameter¹. The magnetic field strength was 161 A/m. The results are shown in the following tables and figures with the susceptibility by volume κ [SI]. A list with the measured samples is displayed before. Especially when the susceptibility of the sample is pretty low an error of measurement can occur at the very high and low frequencies. This is a matter of interspersion from the electricity network or just the measurement technique. This has to be considered in particular for the interpretation of the imaginary part of low susceptibility samples.

¹ www.magnon.de

List of measured samples	Page
<u>Bosnia and Herzegovina</u>	
Tab. 1/Fig. 1: Bzenad, Sehovici, Minefield	3
Tab. 2/Fig. 2: Sehovici, Blind Lane 1	4
<u>Mozambique</u>	
Tab. 3/Fig. 3: Moamba Lane 3	5
Tab. 4/Fig. 4: Moamba Lane 4	6
Tab. 5/Fig. 5: Moamba Lane 6	7
Tab. 6/Fig. 6: Moamba Lane 7	8
<u>Laos</u>	
Tab. 7/Fig. 7: Laos, Site 2, Lane 1	9
Tab. 8/Fig. 8: Laos, Site 2, Lane 2	10
Tab. 9/Fig. 9: Laos, Site 2, Lane 3	11
Tab. 10/Fig. 10: Laos, Site 2, Lane 4	12
Tab. 11/Fig. 11: Laos, Site 2, Test Pit 1	13
Tab. 12/Fig. 12: Laos, Site 2, Test Pit 2	14
Tab. 13/Fig. 13: Laos, Site 3, Test Pit 1, Sample 1	15
Tab. 14/Fig. 14: Laos, Site 3, Test Pit 1, Sample 2	16
Tab. 15/Fig. 15: Laos, Site 3, Test Pit 2, Sample 1	17
Tab. 16/Fig. 16: Laos, Site 3, Test Pit 2, Sample 2	18
Tab. 17/Fig. 17: Laos, Random Sample, Site 3, Loc. 1	19
Tab. 18/Fig. 18: Laos, Random Sample, Site 3, Loc. 2	20
Tab. 19/Fig. 19: Laos, Random Sample, Site 3, Loc. 3	21

Tab. 1: Frequency dependent complex magnetic susceptibility of soil sample "Bzenad, Sehovici, Minefield"

Sample name	f [Hz]	H [A/m]	Real part κ' [10exp-6 SI]	Imaginary part κ'' [10exp-6 SI]
BH2	54	161	725.9	63.0
BH2	105	161	697.4	31.3
BH2	205	161	685.4	48.9
BH2	310	161	674.0	40.6
BH2	510	161	657.3	40.8
BH2	804	161	650.8	
BH2	1060	161	644.0	44.8
BH2	2020	161	627.7	51.6
BH2	3013	161	614.2	56.7
BH2	4993	161	599.0	63.0
BH2	7991	161	588.3	65.7
BH2	9991	161	584.2	61.7

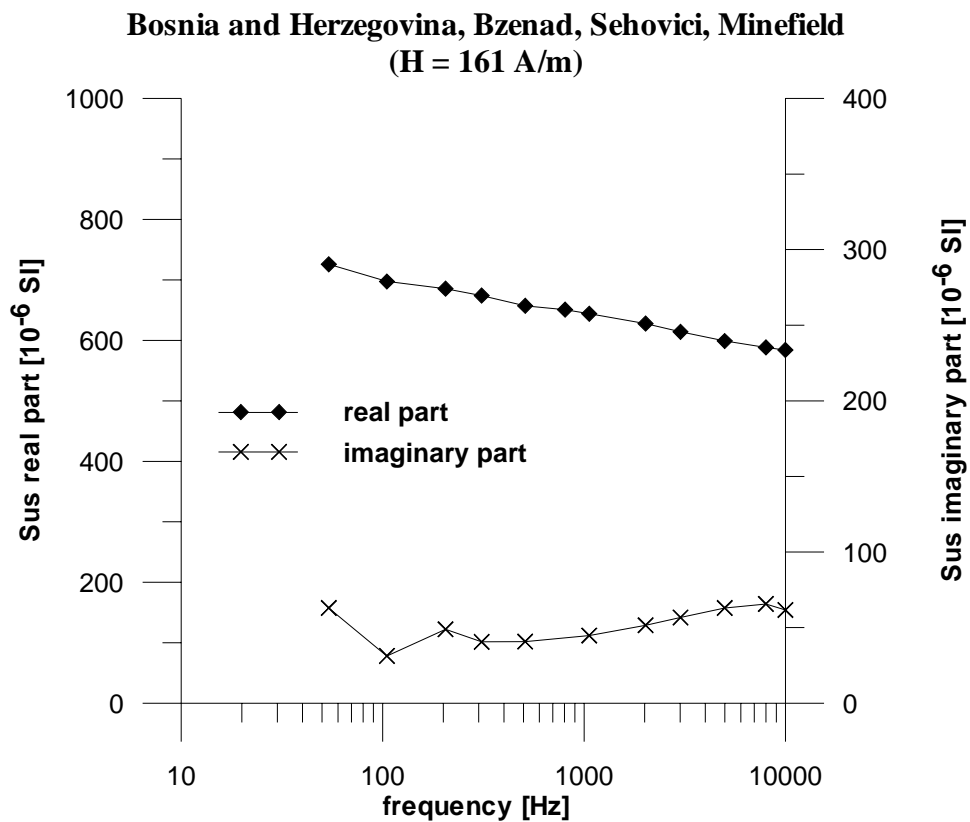


Fig. 1: Frequency dependent complex magnetic susceptibility of soil sample "Bzenad, Sehovici, Minefield"

Tab. 2: Frequency dependent complex magnetic susceptibility of soil sample "Sehovici, Blind Lane 1"

Sample name	f [Hz]	H [A/m]	Real part κ' [10exp-6 SI]	Imaginary part κ'' [10exp-6 SI]
BH3	54	161	756.9	40.7
BH3	105	161	771.6	50.6
BH3	205	161	739.7	46.4
BH3	310	161	724.5	51.5
BH3	510	161	709.9	55.1
BH3	804	161	694.6	56.5
BH3	1060	161	687.5	58.3
BH3	2020	161	664.9	63.5
BH3	3013	161	646.8	69.1
BH3	4993	161	624.4	75.8
BH3	7991	161	616.0	78.2
BH3	9991	161	610.1	73.8

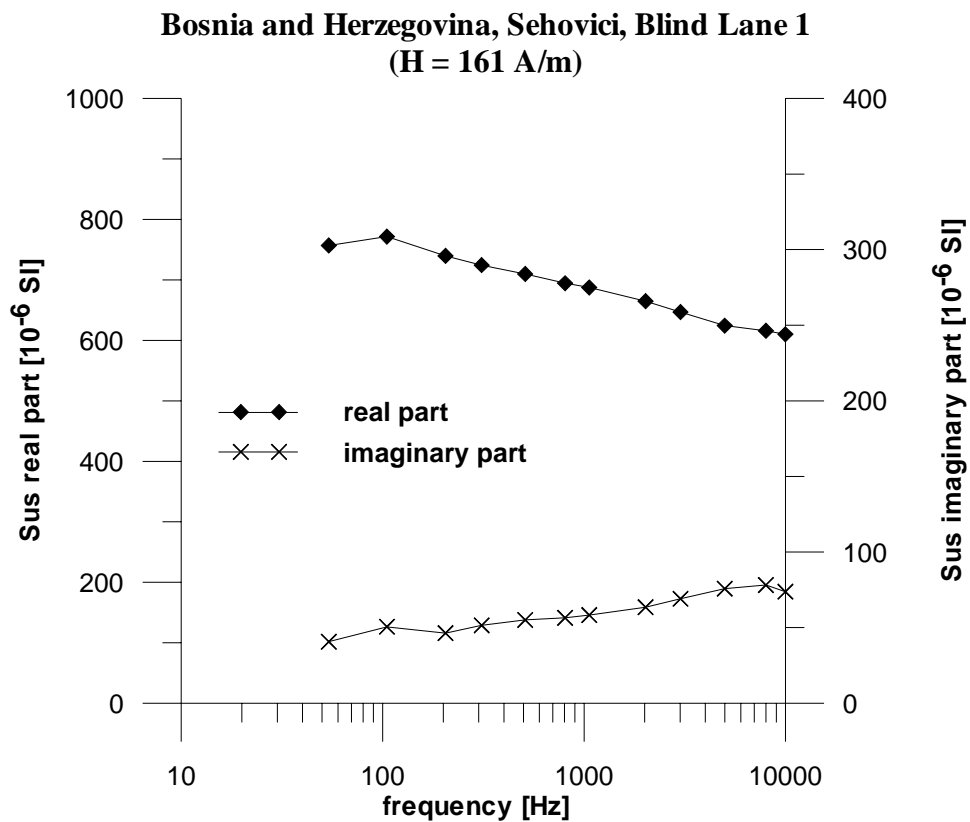


Fig. 2: Frequency dependent complex magnetic susceptibility of soil sample "Sehovici, Blind Lane 1"

Tab. 3: Frequency dependent complex magnetic susceptibility of soil sample "Moamba Lane 3"

Sample name	f [Hz]	H [A/m]	Real part κ' [10exp-6 SI]	Imaginary part κ'' [10exp-6 SI]
M2	54	161	1164.4	54.7
M2	105	161	1146.1	22.8
M2	205	161	1137.1	36.4
M2	310	161	1123.7	31.4
M2	510	161	1114.7	33.2
M2	804	161	1107.9	38.8
M2	1060	161	1100.6	42.2
M2	2020	161	1085.8	53.1
M2	3013	161	1076.0	62.3
M2	4993	161	1061.5	74.6
M2	7991	161	1049.7	79.0
M2	9991	161	1046.1	72.1

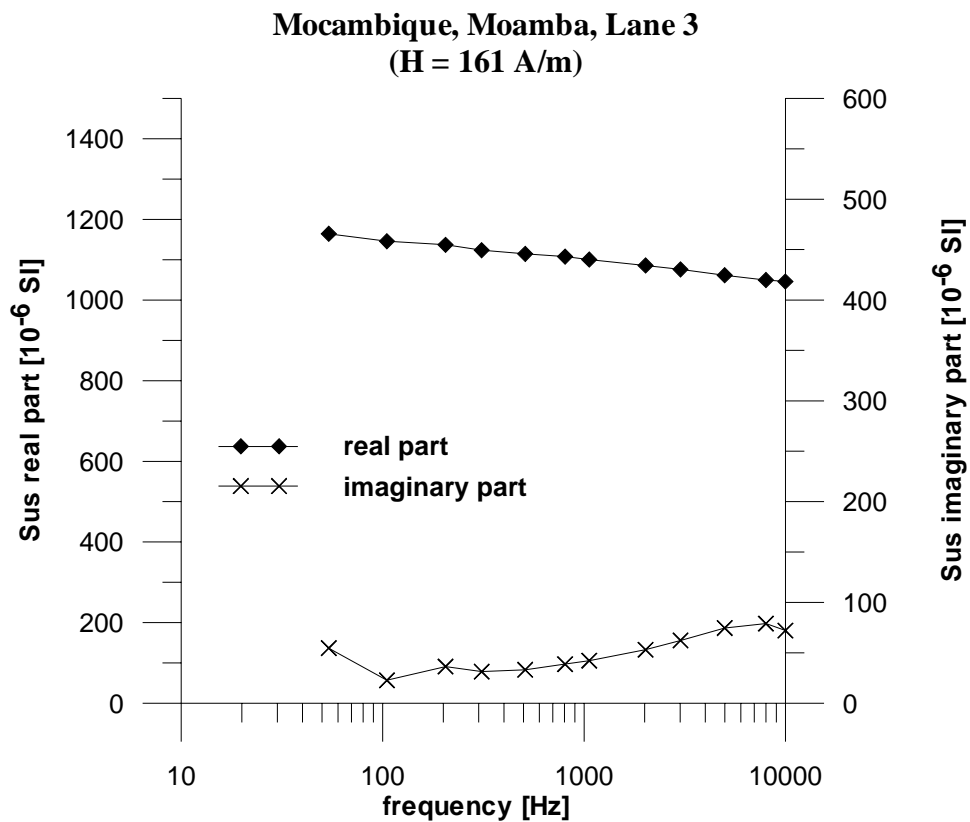


Fig. 3: Frequency dependent complex magnetic susceptibility of soil sample " Moamba Lane 3"

Tab. 4: Frequency dependent complex magnetic susceptibility of soil sample "Moamba Lane 4"

Sample name	f [Hz]	H [A/m]	Real part κ' [10exp-6 SI]	Imaginary part κ'' [10exp-6 SI]
M3	54	161	11539.8	104.3
M3	105	161	11477.0	148.6
M3	205	161	11423.5	159.5
M3	310	161	11385.5	175.9
M3	510	161	11347.2	205.4
M3	804	161	11325.9	241.6
M3	1060	161	11280.5	273.5
M3	2020	161	11192.8	384.7
M3	3013	161	11140.7	481.6
M3	4993	161	11037.9	611.9
M3	7991	161	10959.0	658.3
M3	9991	161	10926.2	582.6

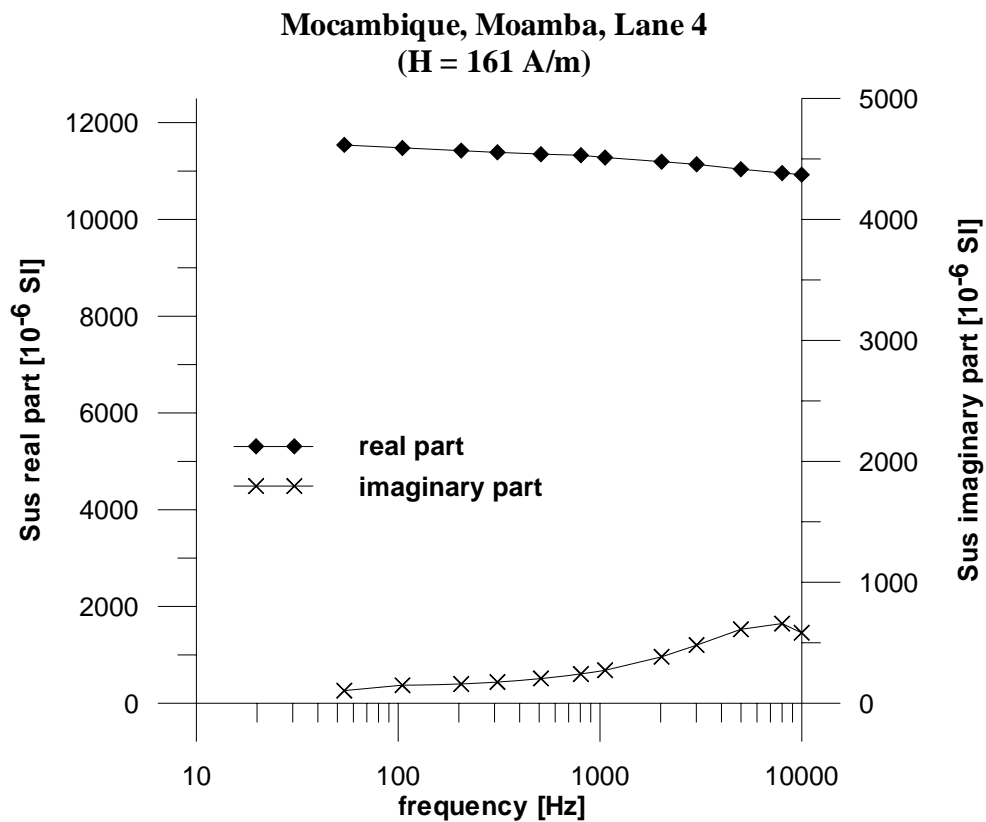


Fig. 4: Frequency dependent complex magnetic susceptibility of soil sample " Moamba Lane 4"

Tab. 5: Frequency dependent complex magnetic susceptibility of soil sample "Moamba Lane 6"

Sample name	f [Hz]	H [A/m]	Real part κ' [10exp-6 SI]	Imaginary part κ'' [10exp-6 SI]
M5	54	161	6101.2	294.9
M5	105	161	5951.3	286.5
M5	205	161	5829.2	297.7
M5	310	161	5742.6	308.5
M5	510	161	5657.5	323.8
M5	804	161	5572.8	344.1
M5	1060	161	5516.8	361.0
M5	2020	161	5384.4	414.7
M5	3013	161	5303.0	461.1
M5	4993	161	5173.0	520.4
M5	7991	161	5056.4	539.5
M5	9991	161	5015.8	504.8

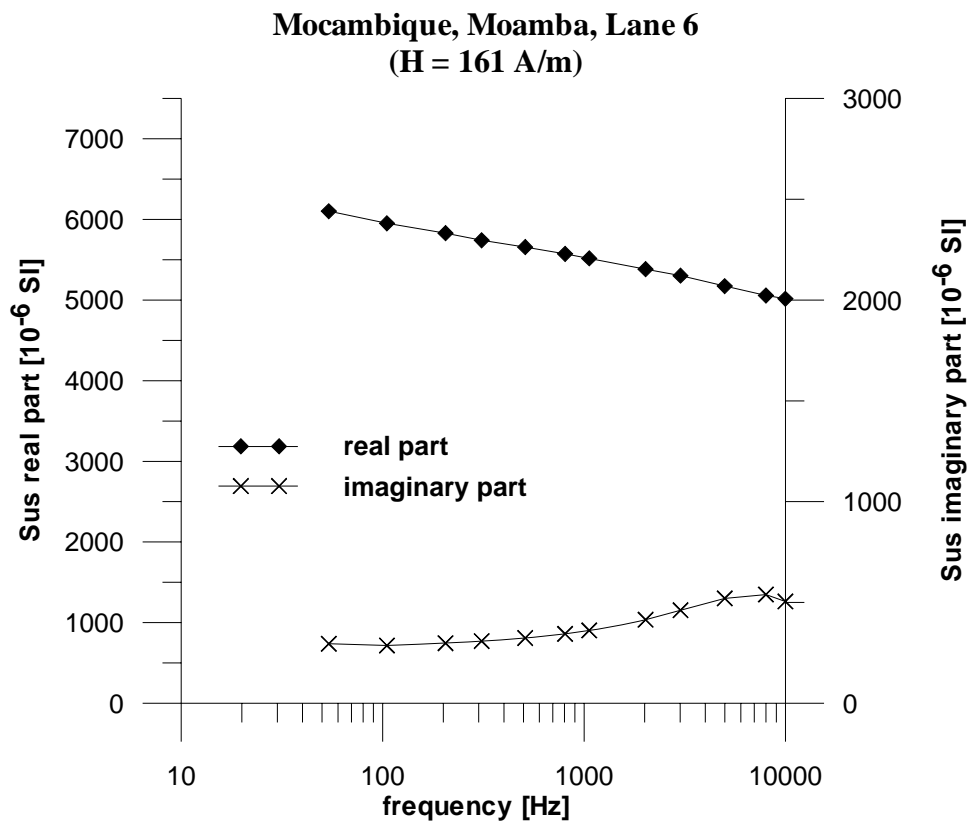


Fig. 5: Frequency dependent complex magnetic susceptibility of soil sample "Moamba Lane 6"

Tab. 6: Frequency dependent complex magnetic susceptibility of soil sample "Moamba Lane 7"

Sample name	f [Hz]	H [A/m]	Real part κ' [10exp-6 SI]	Imaginary part κ'' [10exp-6 SI]
M6	54	161	28466.5	277.0
M6	105	161	28412.3	260.7
M6	205	161	28342.4	314.6
M6	310	161	28301.6	349.6
M6	510	161	28241.2	414.9
M6	804	161	28107.2	509.4
M6	1060	161	28039.2	590.0
M6	2020	161	27944.8	872.1
M6	3013	161	27785.3	1113.9
M6	4993	161	27599.4	1444.3
M6	7991	161	27366.1	1559.3
M6	9991	161	27296.6	1372.2

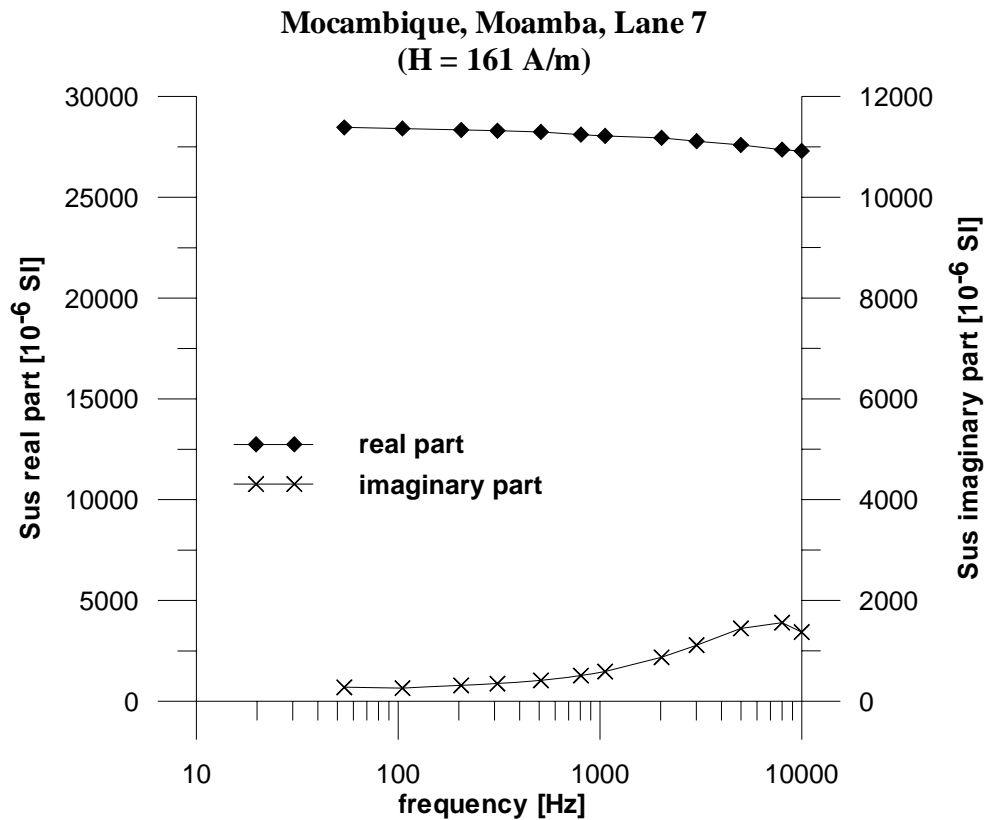


Fig. 6: Frequency dependent complex magnetic susceptibility of soil sample "Moamba Lane 7"

Tab. 7: Frequency dependent complex magnetic susceptibility of soil sample "Laos, Site 2, Lane 1"

Sample name	f [Hz]	H [A/m]	Real part κ' [10exp-6 SI]	Imaginary part κ'' [10exp-6 SI]
LA8	31	161	9673.9	402.4
LA8	54	161	9603.1	415.0
LA8	105	161	9393.3	397.6
LA8	205	161	9266.9	402.1
LA8	310	161	9192.8	415.9
LA8	510	161	9025.1	439.4
LA8	804	161	8932.0	472.9
LA8	1060	161	8848.9	500.5
LA8	2020	161	8674.1	591.8
LA8	3013	161	8551.9	668.5
LA8	4993	161	8374.3	768.1
LA8	7991	161	8204.9	800.8
LA8	9991	161	8159.3	745.8

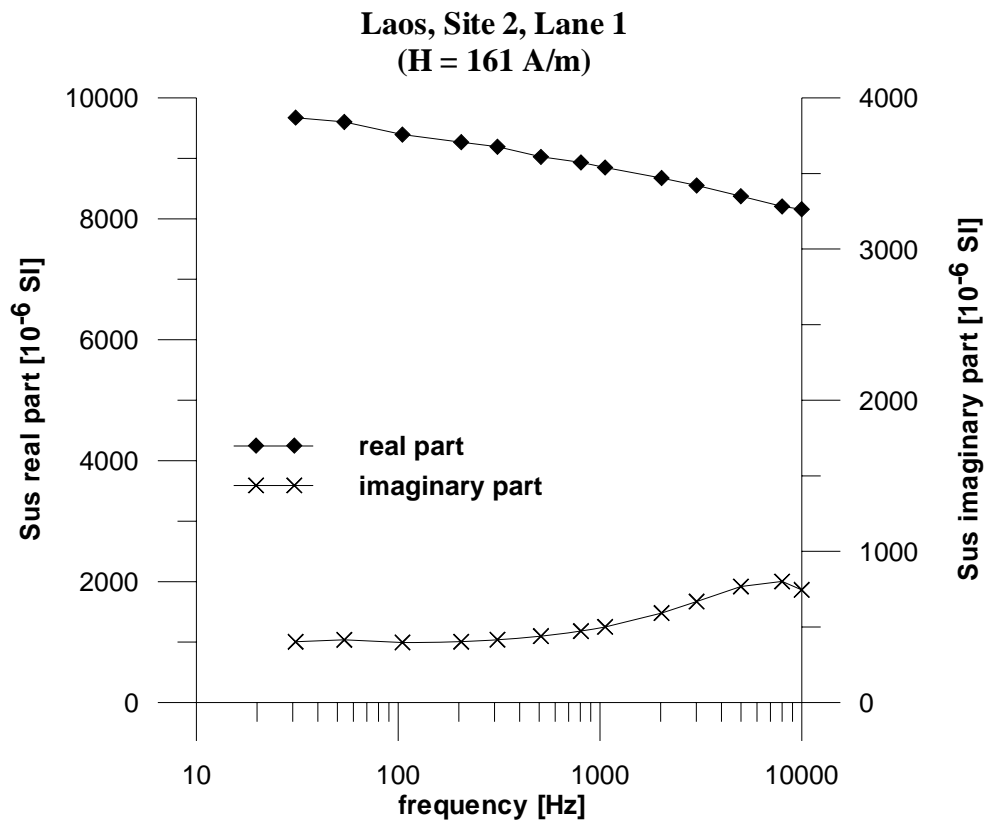


Fig. 7: Frequency dependent complex magnetic susceptibility of soil sample "Laos, Site 2, Lane 1"

Tab. 8: Frequency dependent complex magnetic susceptibility of soil sample "Laos, Site 2, Lane 2"

Sample name	f [Hz]	H [A/m]	Real part κ' [10exp-6 SI]	Imaginary part κ'' [10exp-6 SI]
LA9	31	161	8141.8	252.5
LA9	54	161	8121.1	358.0
LA9	105	161	7970.7	324.0
LA9	205	161	7831.2	356.1
LA9	310	161	7736.2	370.3
LA9	510	161	7626.8	390.7
LA9	804	161	7549.1	418.3
LA9	1060	161	7454.4	437.9
LA9	2020	161	7312.4	516.7
LA9	3013	161	7188.0	577.8
LA9	4993	161	7039.1	660.8
LA9	7991	161	6911.1	690.5
LA9	9991	161	6851.2	642.0

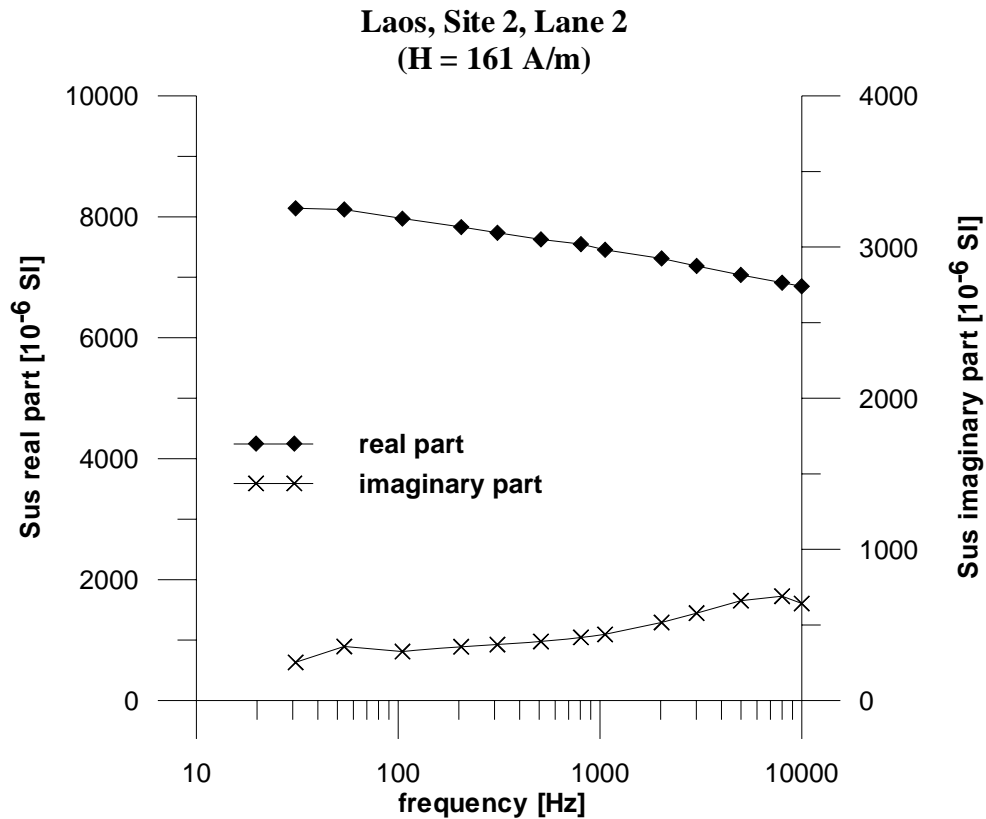


Fig. 8: Frequency dependent complex magnetic susceptibility of soil sample "Laos, Site 2, Lane 2"

Tab. 9: Frequency dependent complex magnetic susceptibility of soil sample "Laos, Site 2, Lane 3"

Sample name	f [Hz]	H [A/m]	Real part κ' [10exp-6 SI]	Imaginary part κ'' [10exp-6 SI]
LA10	31	161	10471.4	376.2
LA10	54	161	10368.5	411.3
LA10	105	161	10176.2	425.2
LA10	205	161	9973.9	441.7
LA10	310	161	9868.4	463.7
LA10	510	161	9675.6	487.7
LA10	804	161	9589.1	527.0
LA10	1060	161	9509.4	558.0
LA10	2020	161	9299.5	655.0
LA10	3013	161	9174.7	737.3
LA10	4993	161	8980.2	844.4
LA10	7991	161	8809.7	881.2
LA10	9991	161	8751.2	821.8

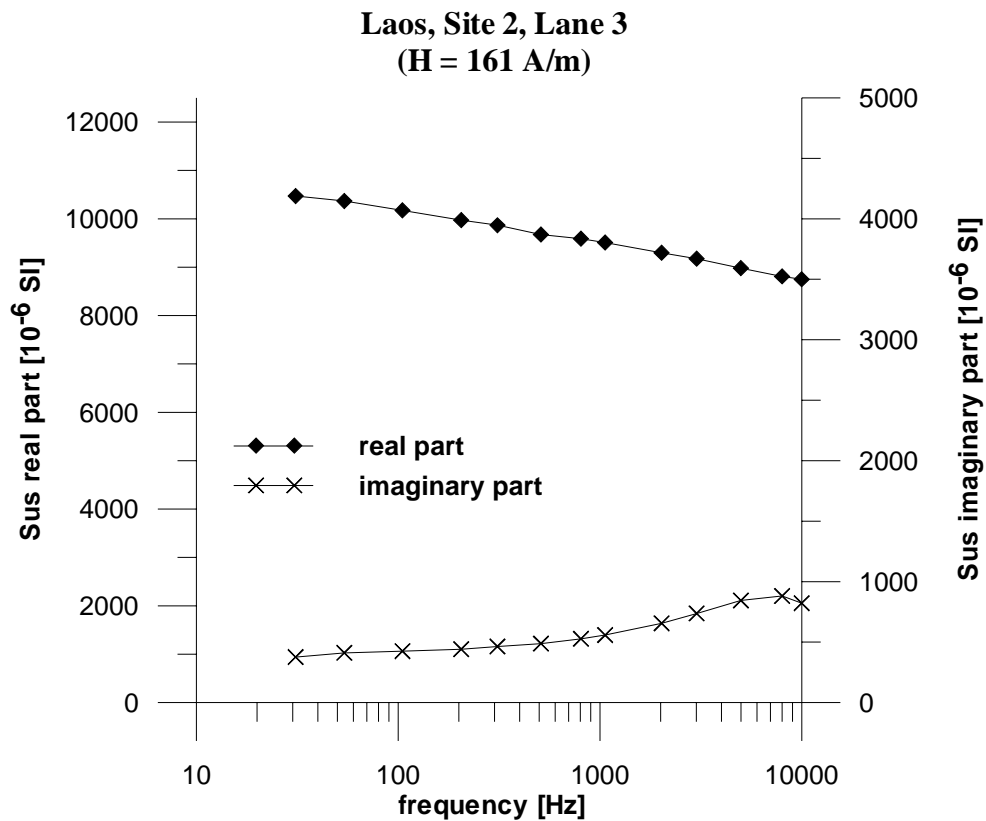


Fig. 9: Frequency dependent complex magnetic susceptibility of soil sample "Laos, Site 2, Lane 3"

Tab. 10: Frequency dependent complex magnetic susceptibility of soil sample "Laos, Site 2, Lane 4"

Sample name	f [Hz]	H [A/m]	Real part κ' [10exp-6 SI]	Imaginary part κ'' [10exp-6 SI]
LA11	31	161	9523.9	415.2
LA11	54	161	9341.9	358.8
LA11	105	161	9213.1	378.1
LA11	205	161	9032.8	397.8
LA11	310	161	8944.5	408.0
LA11	510	161	8832.8	435.7
LA11	804	161	8723.5	470.2
LA11	1060	161	8629.2	494.5
LA11	2020	161	8461.1	584.8
LA11	3013	161	8334.6	658.8
LA11	4993	161	8165.2	756.7
LA11	7991	161	8008.0	790.3
LA11	9991	161	7958.9	736.6

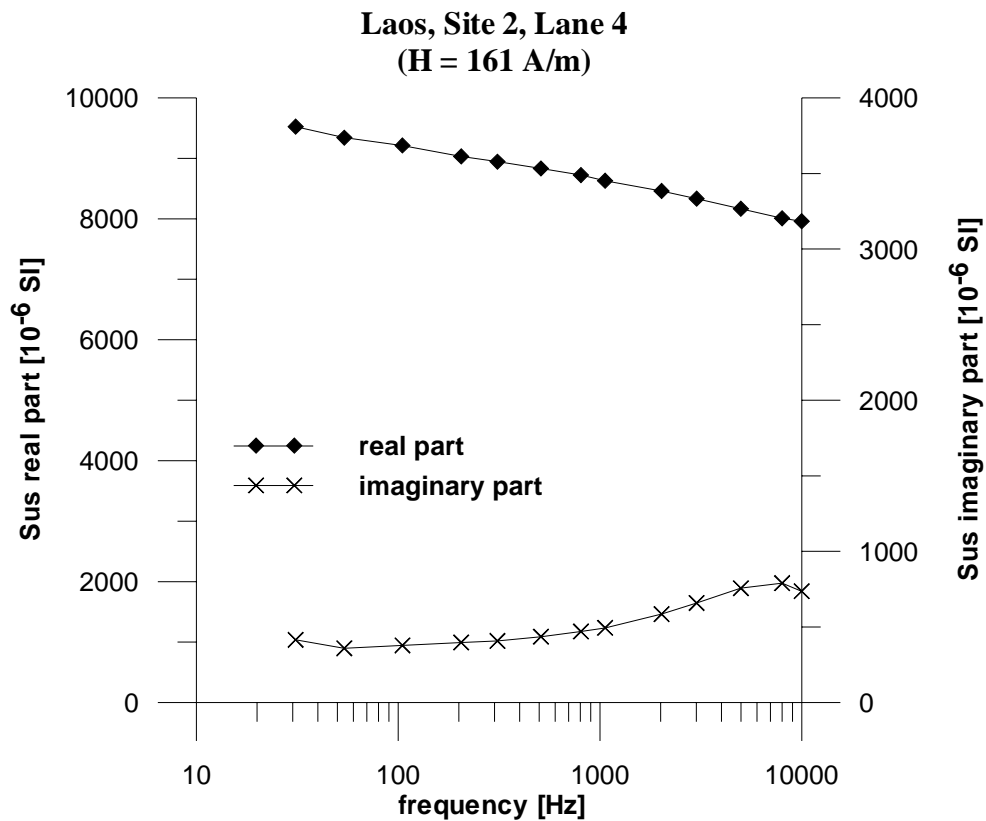


Fig. 10: Frequency dependent complex magnetic susceptibility of soil sample "Laos, Site 2, Lane 4"

Tab. 11: Frequency dependent complex magnetic susceptibility of soil sample
 "Laos, Site 2, Test Pit 1"

Sample name	f [Hz]	H [A/m]	Real part κ' [10exp-6 SI]	Imaginary part κ'' [10exp-6 SI]
LA12	31	161	9929.1	342.5
LA12	54	161	9915.9	365.1
LA12	105	161	9774.5	394.6
LA12	205	161	9549.3	406.4
LA12	310	161	9461.2	426.7
LA12	510	161	9369.5	453.7
LA12	804	161	9247.4	486.4
LA12	1060	161	9171.1	513.0
LA12	2020	161	8983.7	608.1
LA12	3013	161	8877.6	687.4
LA12	4993	161	8665.1	788.7
LA12	7991	161	8529.4	826.4
LA12	9991	161	8474.4	767.8

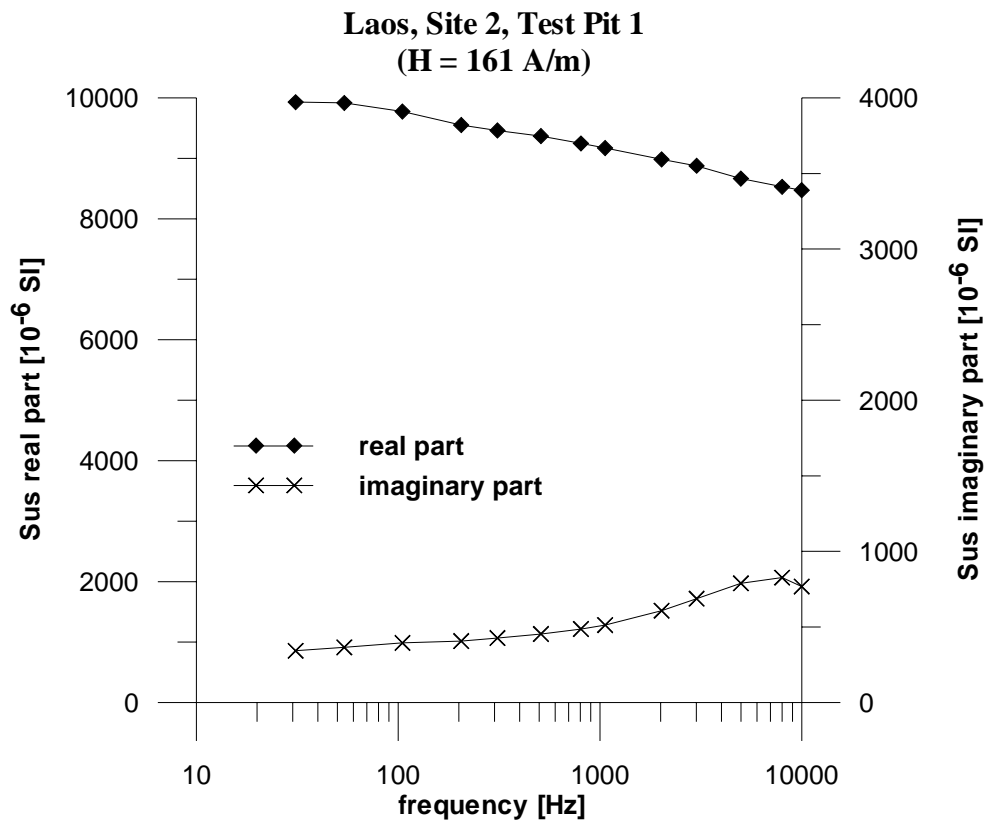


Fig. 11: Frequency dependent complex magnetic susceptibility of soil sample
 "Laos, Site 2, Test Pit 1"

Tab. 12: Frequency dependent complex magnetic susceptibility of soil sample "Laos, Site 2, Test Pit 2"

Sample name	f [Hz]	H [A/m]	Real part κ' [10exp-6 SI]	Imaginary part κ'' [10exp-6 SI]
LA13	31	161	10465.6	395.6
LA13	54	161	10359.9	410.8
LA13	105	161	10171.4	431.3
LA13	205	161	9995.8	438.2
LA13	310	161	9887.7	449.9
LA13	510	161	9772.1	483.3
LA13	804	161	9623.5	517.4
LA13	1060	161	9519.6	544.6
LA13	2020	161	9387.4	645.5
LA13	3013	161	9248.4	726.5
LA13	4993	161	9055.8	834.0
LA13	7991	161	8877.0	869.5
LA13	9991	161	8817.8	808.9

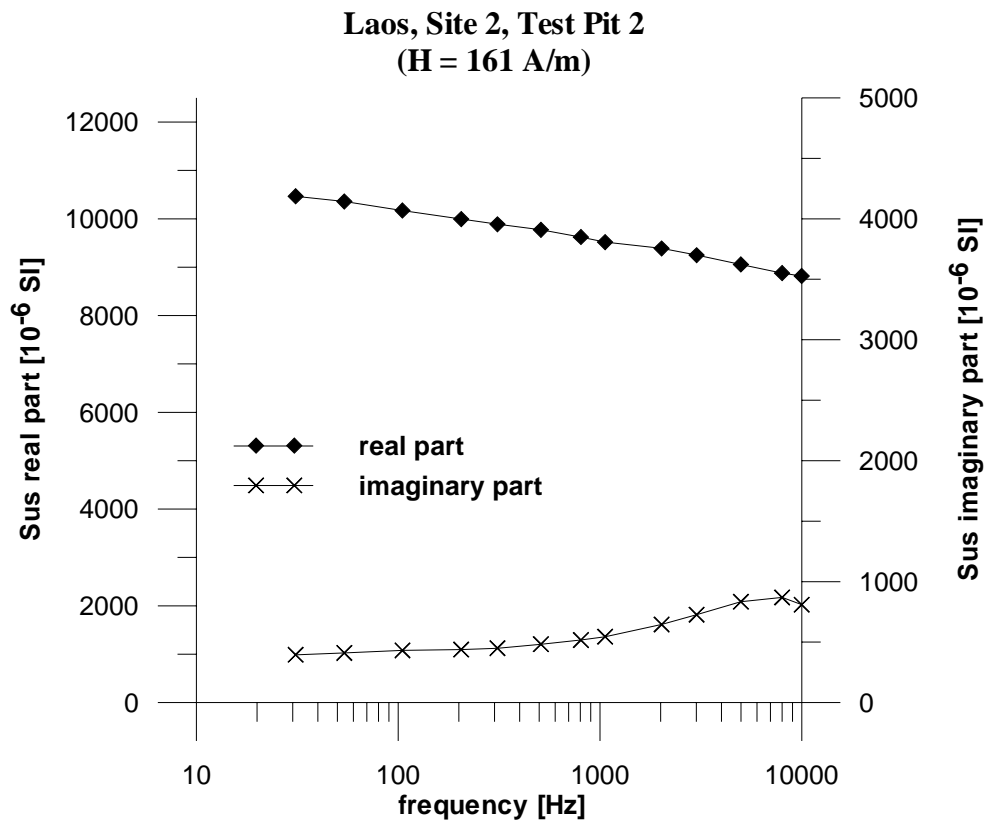


Fig. 12: Frequency dependent complex magnetic susceptibility of soil sample "Laos, Site 2, Test Pit 2"

Tab. 13: Frequency dependent complex magnetic susceptibility of soil sample
 "Laos, Site 3, Test Pit 1, Sample 1"

Sample name	f [Hz]	H [A/m]	Real part κ' [10exp-6 SI]	Imaginary part κ'' [10exp-6 SI]
LA14	54	161	26184.1	1707.8
LA14	105	161	25522.7	1699.6
LA14	205	161	24833.4	1749.0
LA14	310	161	24389.5	1788.0
LA14	510	161	23886.8	1855.7
LA14	804	161	23359.0	1935.2
LA14	1060	161	23052.1	2004.9
LA14	2020	161	22296.9	2229.2
LA14	3013	161	21769.4	2410.8
LA14	4993	161	21103.1	2646.2
LA14	7991	161	20500.3	2713.3
LA14	9991	161	20227.3	2560.1

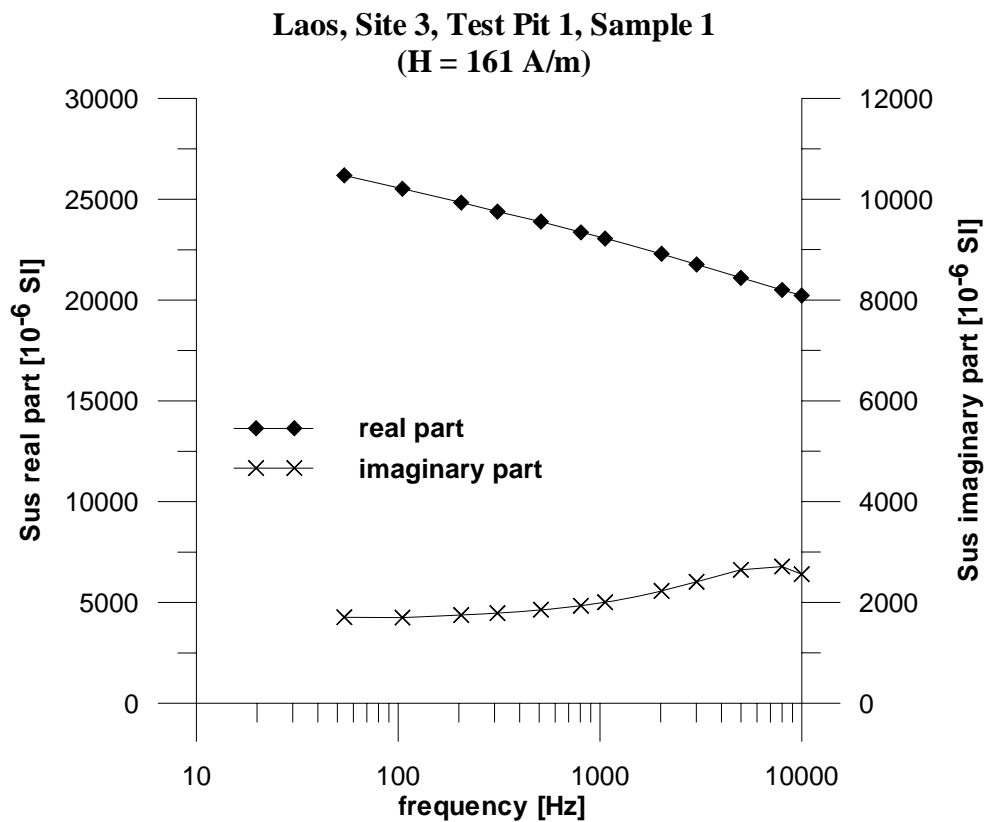


Fig. 13: Frequency dependent complex magnetic susceptibility of soil sample
 "Laos, Site 3, Test Pit 1, Sample 1"

Tab. 14: Frequency dependent complex magnetic susceptibility of soil sample
 "Laos, Site 3, Test Pit 1, Sample 2"

Sample name	f [Hz]	H [A/m]	Real part κ' [10exp-6 SI]	Imaginary part κ'' [10exp-6 SI]
LA15	54	161	25035.7	1582.2
LA15	105	161	24391.8	1577.9
LA15	205	161	23728.7	1624.4
LA15	310	161	23308.1	1660.6
LA15	510	161	22795.7	1727.1
LA15	804	161	22335.1	1808.0
LA15	1060	161	22101.9	1876.6
LA15	2020	161	21375.9	2090.8
LA15	3013	161	20863.8	2264.1
LA15	4993	161	20241.2	2492.5
LA15	7991	161	19727.0	2565.0
LA15	9991	161	19427.4	2412.8

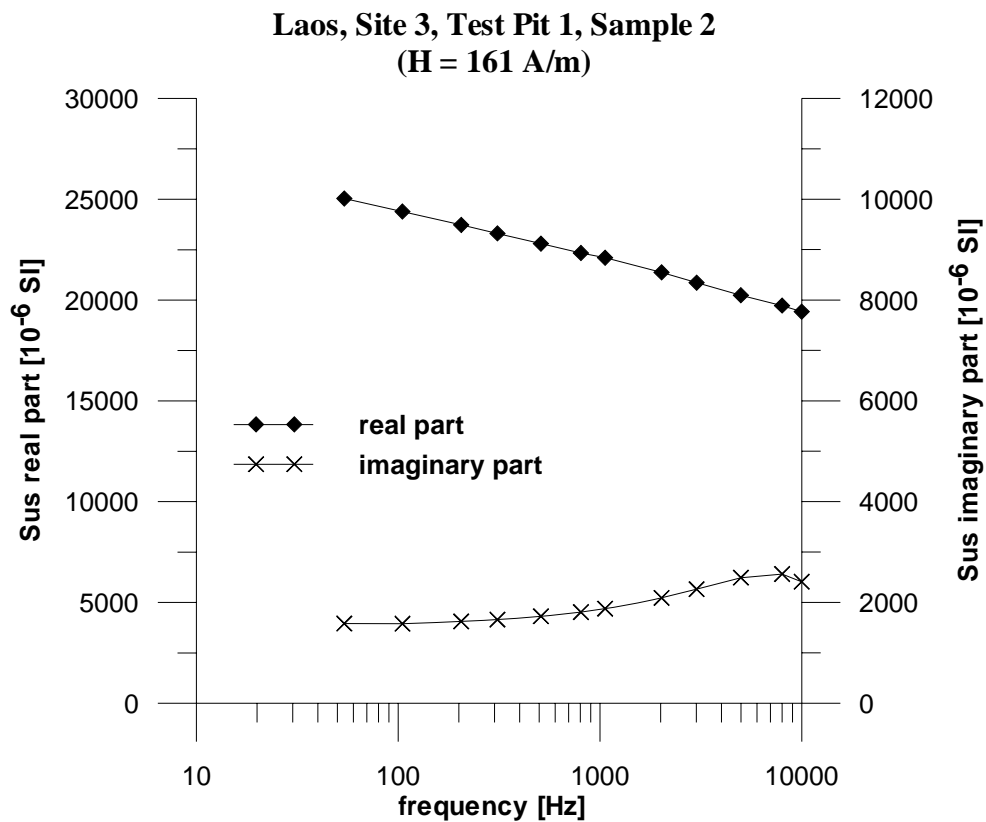


Fig. 14: Frequency dependent complex magnetic susceptibility of soil sample
 "Laos, Site 3, Test Pit 1, Sample 2"

Tab. 15: Frequency dependent complex magnetic susceptibility of soil sample
 "Laos, Site 3, Test Pit 2, Sample 1"

Sample name	f [Hz]	H [A/m]	Real part κ' [10exp-6 SI]	Imaginary part κ'' [10exp-6 SI]
LA16	54	161	23067.8	571.9
LA16	105	161	22879.1	580.8
LA16	205	161	22671.2	616.9
LA16	310	161	22505.1	649.8
LA16	510	161	22326.1	707.3
LA16	804	161	22190.5	787.3
LA16	1060	161	22048.9	852.0
LA16	2020	161	21814.2	1074.4
LA16	3013	161	21587.7	1261.6
LA16	4993	161	21266.6	1512.7
LA16	7991	161	21005.9	1601.2
LA16	9991	161	20939.0	1459.1

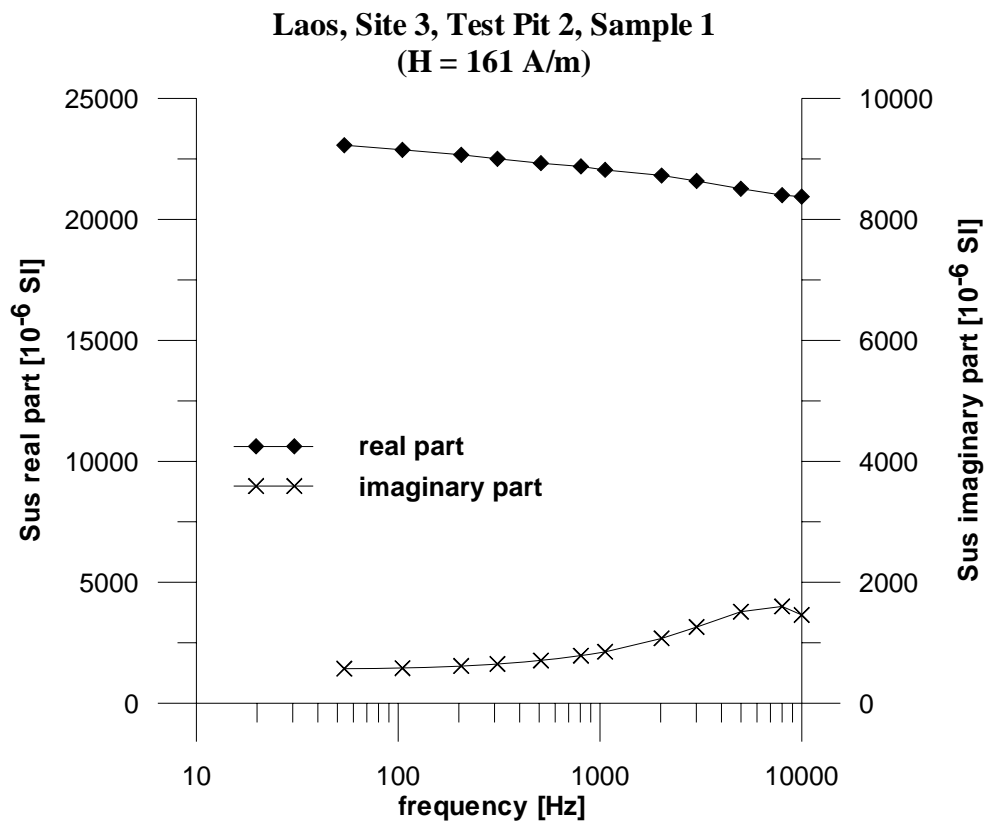


Fig. 15: Frequency dependent complex magnetic susceptibility of soil sample
 "Laos, Site 3, Test Pit 2, Sample 1"

Tab. 16: Frequency dependent complex magnetic susceptibility of soil sample
 "Laos, Site 3, Test Pit 2, Sample 2"

Sample name	f [Hz]	H [A/m]	Real part κ' [10exp-6 SI]	Imaginary part κ'' [10exp-6 SI]
LA17	54	161	21752.8	574.5
LA17	105	161	21515.3	593.5
LA17	205	161	21233.8	625.1
LA17	310	161	21121.8	656.3
LA17	510	161	20944.3	715.9
LA17	804	161	20749.6	783.0
LA17	1060	161	20614.8	843.5
LA17	2020	161	20363.5	1050.6
LA17	3013	161	20121.0	1223.9
LA17	4993	161	19837.7	1459.5
LA17	7991	161	19569.9	1540.1
LA17	9991	161	19493.7	1407.1

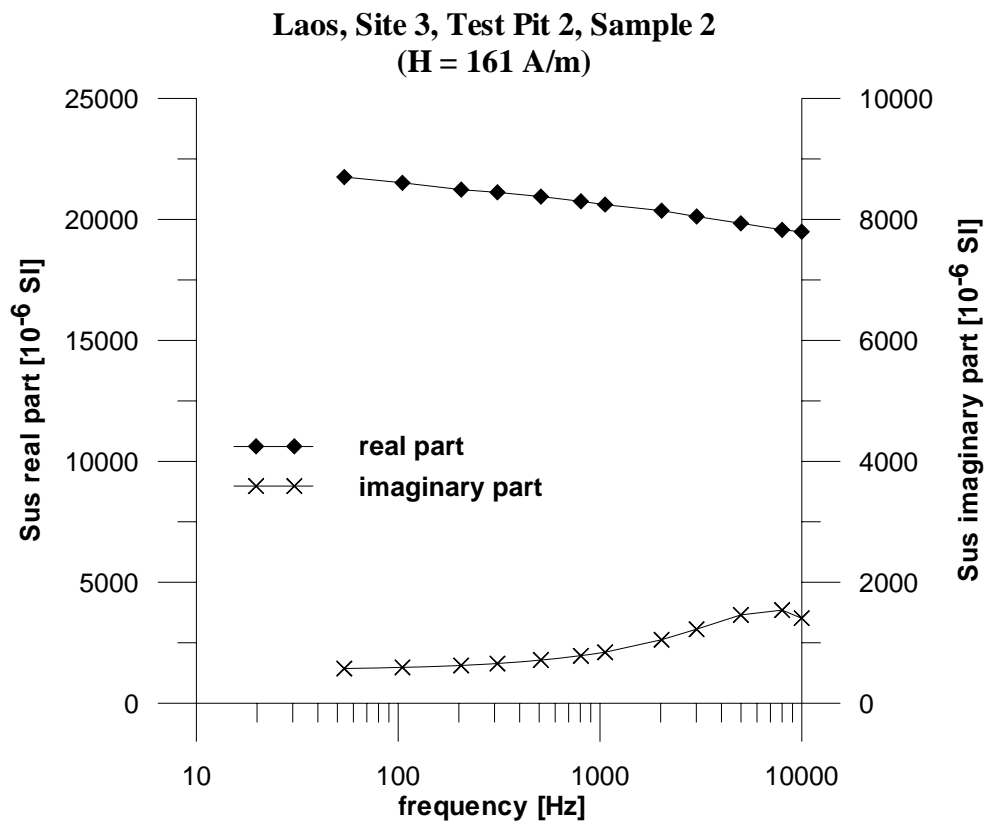


Fig. 16: Frequency dependent complex magnetic susceptibility of soil sample
 "Laos, Site 3, Test Pit 2, Sample 2"

Tab. 17: Frequency dependent complex magnetic susceptibility of soil sample
 "Laos, Random Sample, Site 3, Loc. 1"

Sample name	f [Hz]	H [A/m]	Real part κ' [10exp-6 SI]	Imaginary part κ'' [10exp-6 SI]
LA18	54	161	70276.2	3118.1
LA18	105	161	69049.8	3241.3
LA18	205	161	67729.2	3414.5
LA18	310	161	66758.1	3543.1
LA18	510	161	65716.5	3758.0
LA18	804	161	64801.1	4037.4
LA18	1060	161	64150.7	4251.5
LA18	2020	161	62533.7	4953.7
LA18	3013	161	61490.4	5535.6
LA18	4993	161	60034.3	6306.7
LA18	7991	161	58862.3	5359.3
LA18	9991	161	58162.2	4650.9

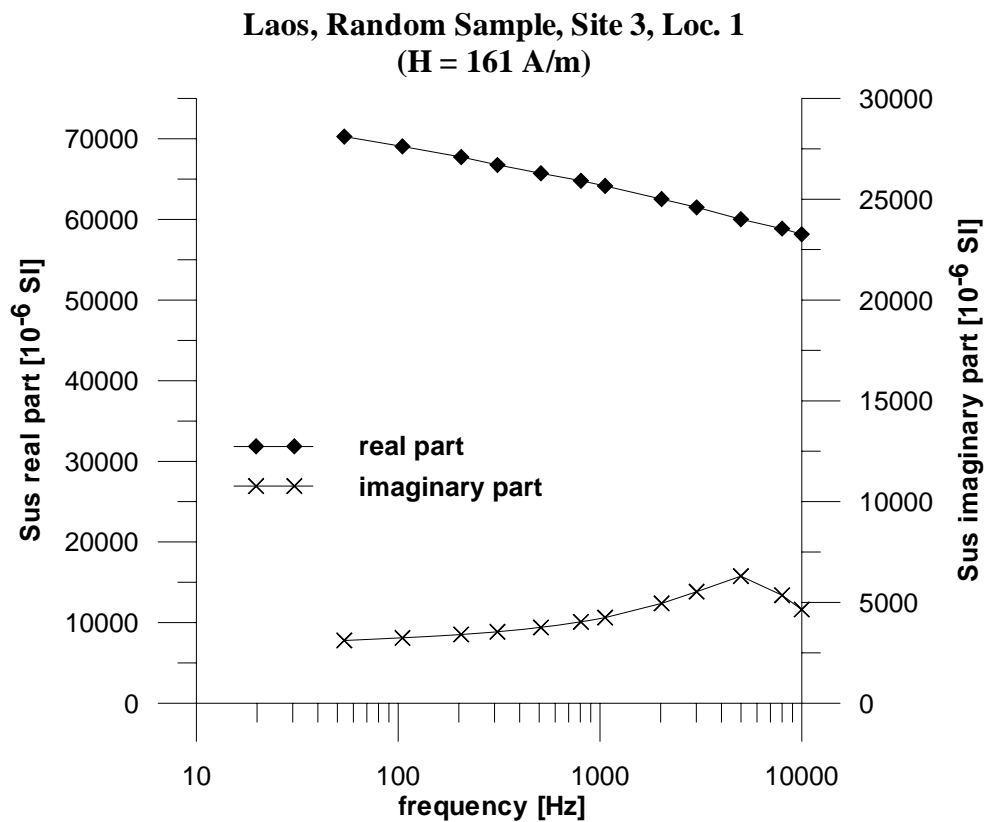


Fig. 17: Frequency dependent complex magnetic susceptibility of soil sample
 "Laos, Random Sample, Site 3, Loc. 1"

Tab. 18: Frequency dependent complex magnetic susceptibility of soil sample
 "Laos, Random Sample, Site 3, Loc. 2"

Sample name	f [Hz]	H [A/m]	Real part κ' [10exp-6 SI]	Imaginary part κ'' [10exp-6 SI]
LA19	54	161	77342.1	3651.1
LA19	105	161	75820.9	3810.9
LA19	205	161	74180.7	4029.8
LA19	310	161	73125.5	4211.3
LA19	510	161	71899.9	4484.4
LA19	804	161	70687.3	4817.3
LA19	1060	161	69904.6	5072.8
LA19	2020	161	67907.9	5884.5
LA19	3013	161	66596.4	6546.2
LA19	4993	161	64833.1	7424.8
LA19	7991	161	63405.8	6415.4
LA19	9991	161	62613.4	5672.7

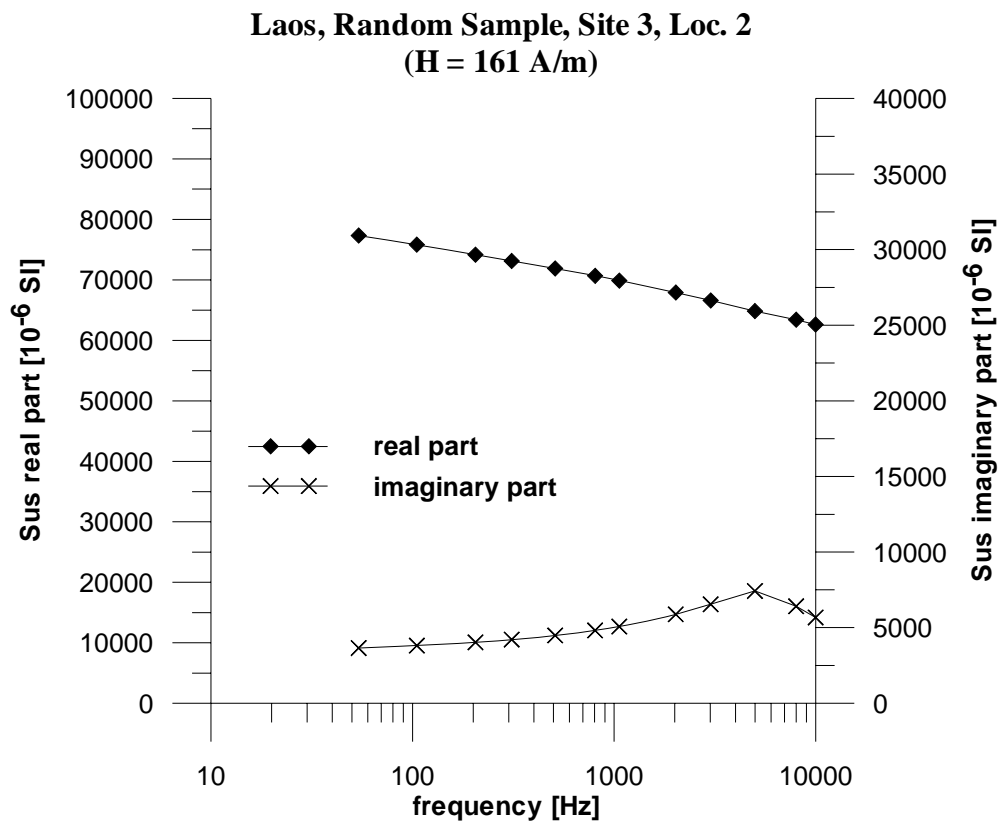


Fig. 18: Frequency dependent complex magnetic susceptibility of soil sample
 "Laos, Random Sample, Site 3, Loc. 2"

Tab. 19: Frequency dependent complex magnetic susceptibility of soil sample
 "Laos, Random Sample, Site 3, Loc. 3"

Sample name	f [Hz]	H [A/m]	Real part κ' [10exp-6 SI]	Imaginary part κ'' [10exp-6 SI]
LA20	54	161	115710.2	5044.2
LA20	105	161	113655.7	5308.9
LA20	205	161	111171.0	5603.8
LA20	310	161	109877.3	5858.6
LA20	510	161	108051.5	6242.3
LA20	804	161	106489.0	6738.8
LA20	1060	161	105347.4	7114.8
LA20	2020	161	102747.2	8363.7
LA20	3013	161	100608.3	9349.3
LA20	4993	161	98464.6	9255.5
LA20	7991	161	96099.1	8957.8
LA20	9991	161	95422.2	7835.5

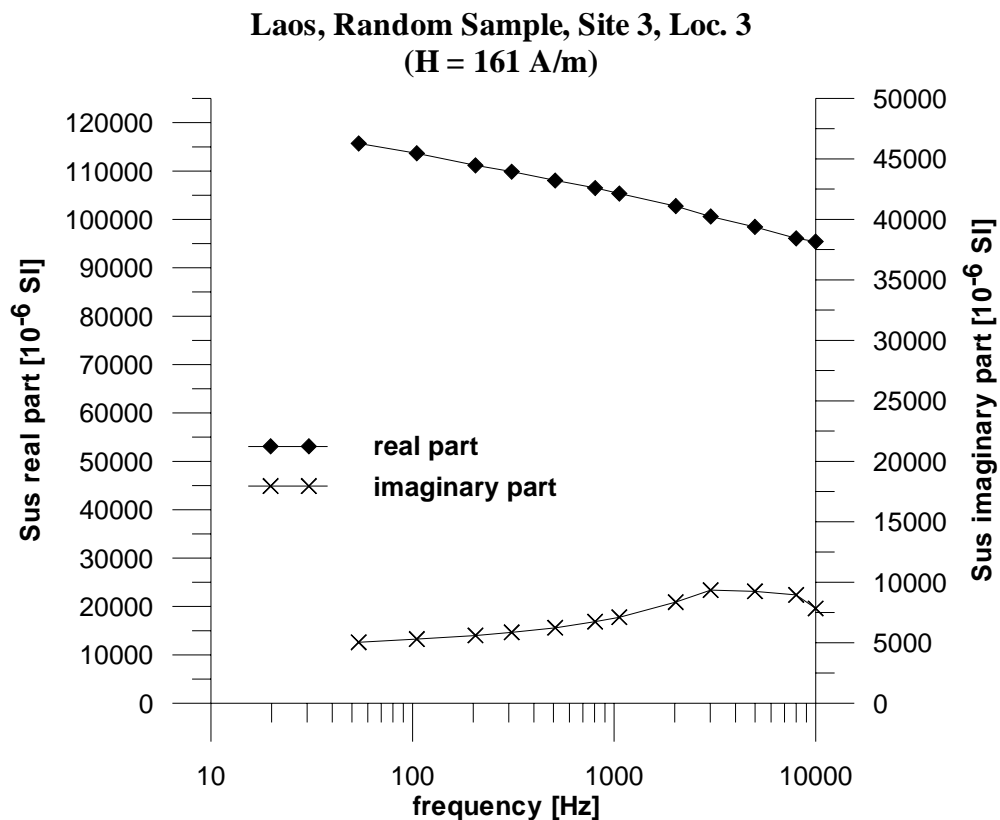


Fig. 19: Frequency dependent complex magnetic susceptibility of soil sample
 "Laos, Random Sample, Site 3, Loc. 3"