Testing the EH Antenna: Part 1

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My interest in investigating the EH antennas started because I was interested in buying them to use in my work. I am the Network Director of the "World Family of Radio Maria," a Catholic radio network that has broadcasting stations in 27 different countries of the world. Since we also have some AM stations in the lower part of the band, I was attracted to search for proofs if something really new has been discovered in the field of compact antennas, and I visited Ted Hart near Atlanta. He kindly showed me his concepts, but he didn't show me any practical proof. I offered my expertise in measuring antennas and the use of the instruments I have to validate (or not) the theories behind the EH antenna.

I then met in Italy Stefano Galastri and Marco Menozzi, who build and sells the EH antennas in Europe. This article reports about the tests, calculations, and results that I have carried out during some months to check if the specs claimed for the EH antennas are true and if an "EH antenna concept " exists or if all is explained by the classic and well-known Hertzian theory.

SYSTEM DESIGN

The frequency of 50 MHz (λ = 6 meters) was chosen to allow easy field tests for gain, radiation pattern, and efficiency. A distance between the test antennas of 12 m (2λ) allows a fairly good accuracy.

***Classical Hertzian Theory*:**

The Hertzian teory dictates that the amount of the Radiation Resistance (Rr) of a very short open antenna (about 2% of λ) lies in the range of 0.1- 0.3 Ohm. The impedance is capacitive and very high. Capacitance can be resonated in a narrow band (high Q) with the aid of a coil, and the Rr transformed to 50 Ohms with a matching network. The theoretical gain of the antenna is – 0.4 dB in respect to the dipole. Anyway, with this low value of Rr, every minimum loss lowers efficiency and so the total gain. Examples of calculations and tables will show how much.

***EH theory*:**

EH theory is similar to the Hertzian theory, but claims that, when the phase of the network is 180°, the Rr rises to typical values of 10 ohm, allowing high efficiency and low Q (broadband). Other claims are that the unique shape of the antenna allows it to concentrate the radiation pattern and so increase the gain.

RESULTS OF CALCULATIONS

The calculation was performed using the software NOVA. Despite the fact that it works in DOS, the software has a very good graphical interface and every component can be easily tuned continuously in real time allowing optimization. The Q of each reactive component can be set separately. I have used this software for 15 years minimum and it has alway been very accurate.

The values of the network were taken from the EH official site and visualized in **Fig. 1** for the bicone version of the antenna. The first simulation showed the best Return loss (RL) for Rr = 8 ohm, the phase was 180° at resonance. The loss of the network was 1.2 dB, Efficiency: 76%, Q = 38: see **Fig. 2** and **Table 1**.

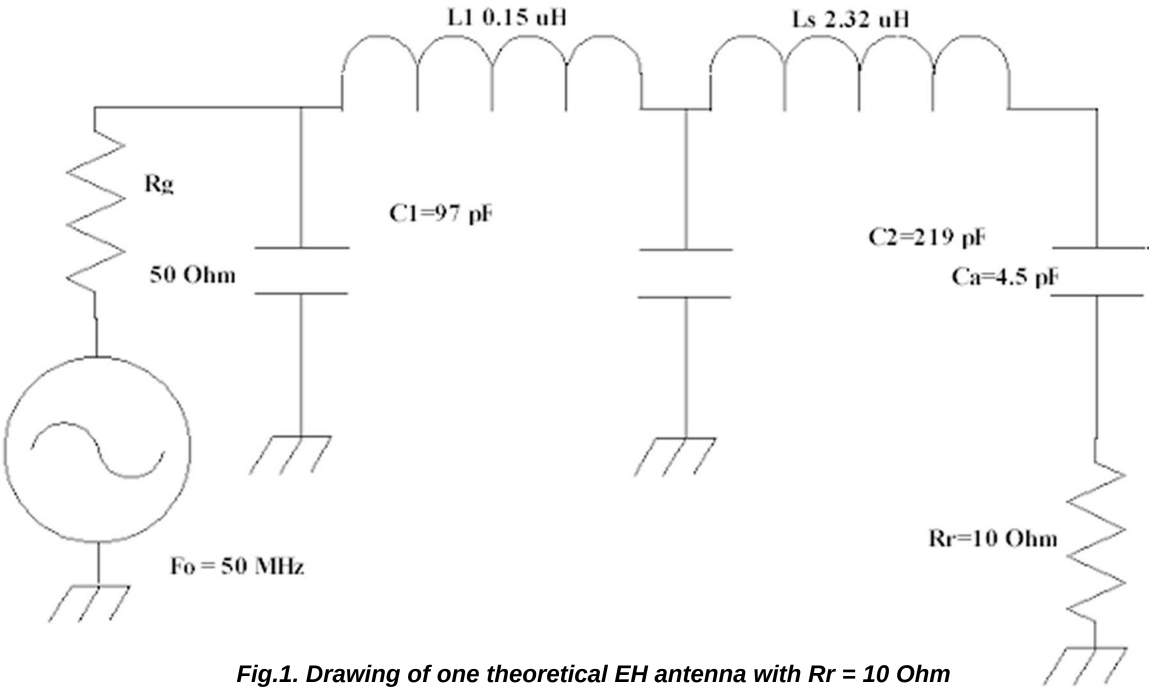

Fig.1. Drawing of one theoretical EH antenna with Rr = 10 Ohm

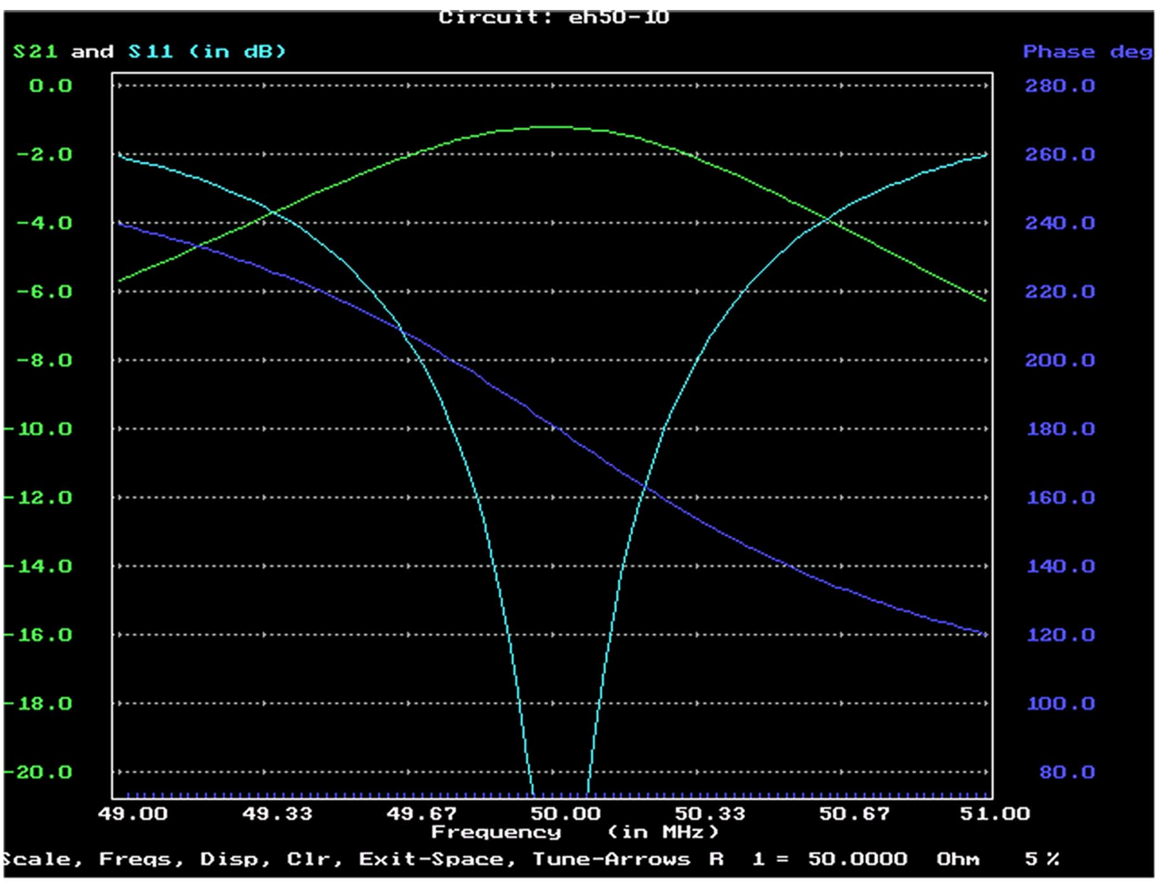

Fig. 2. Transfer Function – Return Loss and Phase of one theoretical EH antenna with Rr = 8 Ohm. (Ed: Note that the European "comma" has been left in place of the Western "decimal point")

The most important component that affects Loss and thus efficiency is Ls, due to its high value. In the practical realization, I wound it as an air-core inductor with copper of 2 mm silver plated, using a 2.5 cm diameter. I measured its Q with a Marconi Q-meter TF1245A at 450; that is very high. The coils observed at the EH site seem very much worse.

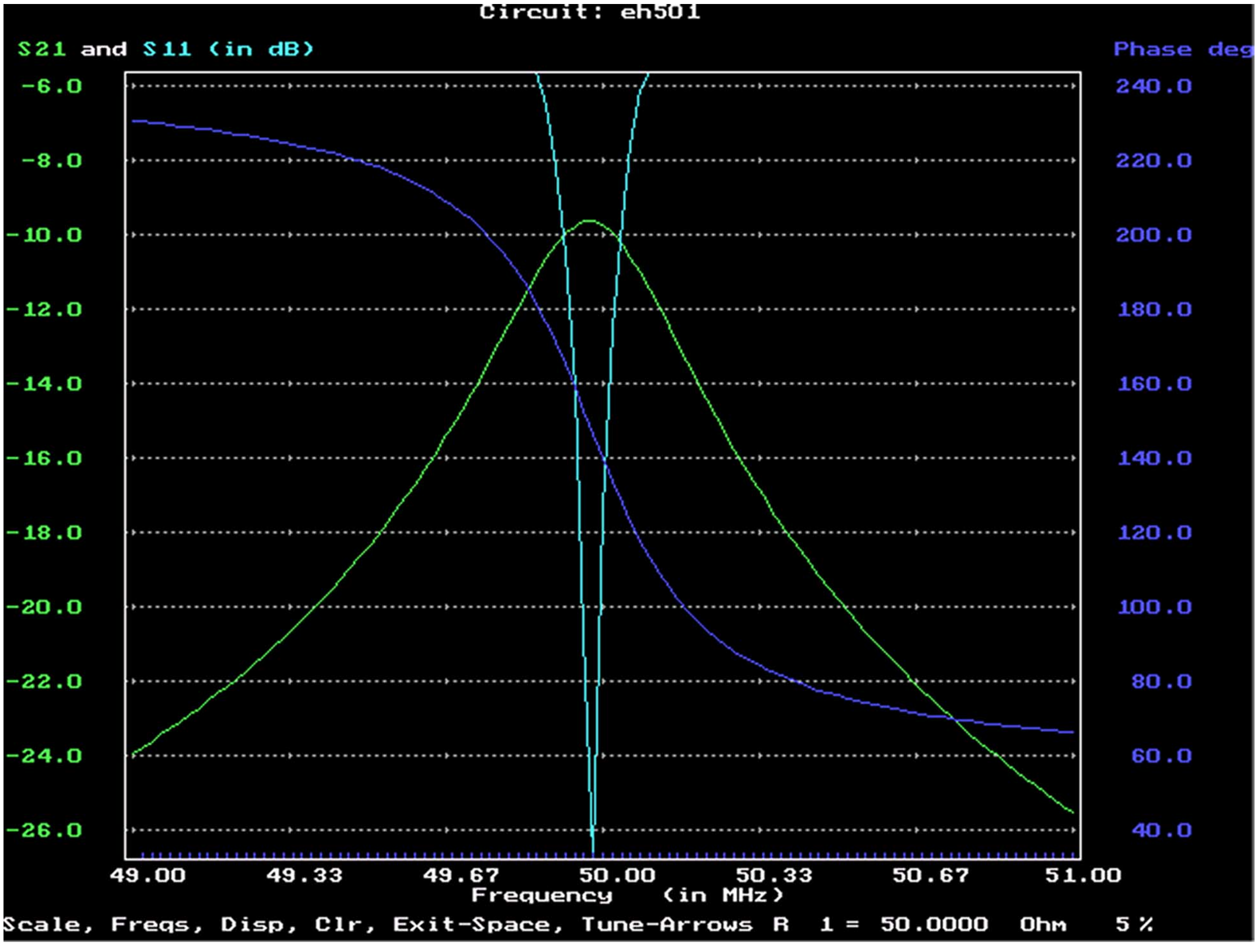

Fig.3. Transfer Function – Return Loss and Phase of one Hertzian antenna with Rr = 0,3 Ohm.

Calculations on the coil with Q = 450 give an equivalent loss series resistance Rs of 1.6 Ohm. Despite the high Q, the loss of the total network, with the assumption of Rr = 10 Ohm, gives an efficiency of 76% (calculated from the overall loss in dB). An efficiency of 95% requires a Loss of only 0,22 dB. See Fig. 4a and Fig. 4b.

NOVA does not have the ability to calculate S parameters which are normalized with two different impedances at input and outputs as has to be done in this case. But, these calculations were made by a friend with a more powerful software called MWOFFICE that does have the ability. It shows losses of 0.74 dB (Efficiency = 84%) instead of my first rough calculations of 1.2 dB (Efficiency =76%). Either calculation of efficiency is still very far from 95% and thus, it is not possible to believe any claims of efficiency equal or better than the 95%. But, if we want to calculate the efficiency in a more precise intuitive way and at the same time be conservative in the interest of those who claim a higher efficiency, we can demonstrate this without the use of software:

If we want to calculate what Rr is needed to have an efficiency of 95 %, assuming the most favourable condition that losses are only due to the Rs of Ls, we calculate this way:

$$\eta = Rr/(Rs+Rr) = 0.95$$

Solving for Rr:

$$Rr = 19Rs = 30.4 \text{ Ohm.}$$

It is easy to understand that this value is outside of discussion for the small antenna. The graphics of the calculations for Efficiency and Loss respect to Rr, made for various Q, are plotted in Fig. 4c and Fig. 4d, and once again clearly demonstrate the thesis, showing the points at η = 95 % for various Q (Rr = 30.4 Ohm for Q = 450). Just for example, you can see that with a Q = 100 you never reach 95 % of efficiency even if Rr = 100 Ohm! Further physical proof will also be shown in other parts of the article.

Fig.	RL	B	Q	Rs	Rr	Loss	Efficiency	Phase	C1	L1	Q1	C2	Ls	Q2	Ca
	dB	MHz		Ohm	Ohm	dB	%	°	pF	uH		pF	uH		pF
2	26	1,3	38	1,6	8	1,2	76	180,0	97	0,15	160	219	2,3	450	4,5
3	26	0,35	143	1,6	0,3	9,6	11	145,0	97	0,22	160	219	2,3	450	4,5
4	26	0,35	143	1,6	0,3	9,6	11	180,0	52	0,25	160	219	2,3	450	4,5

Table 1

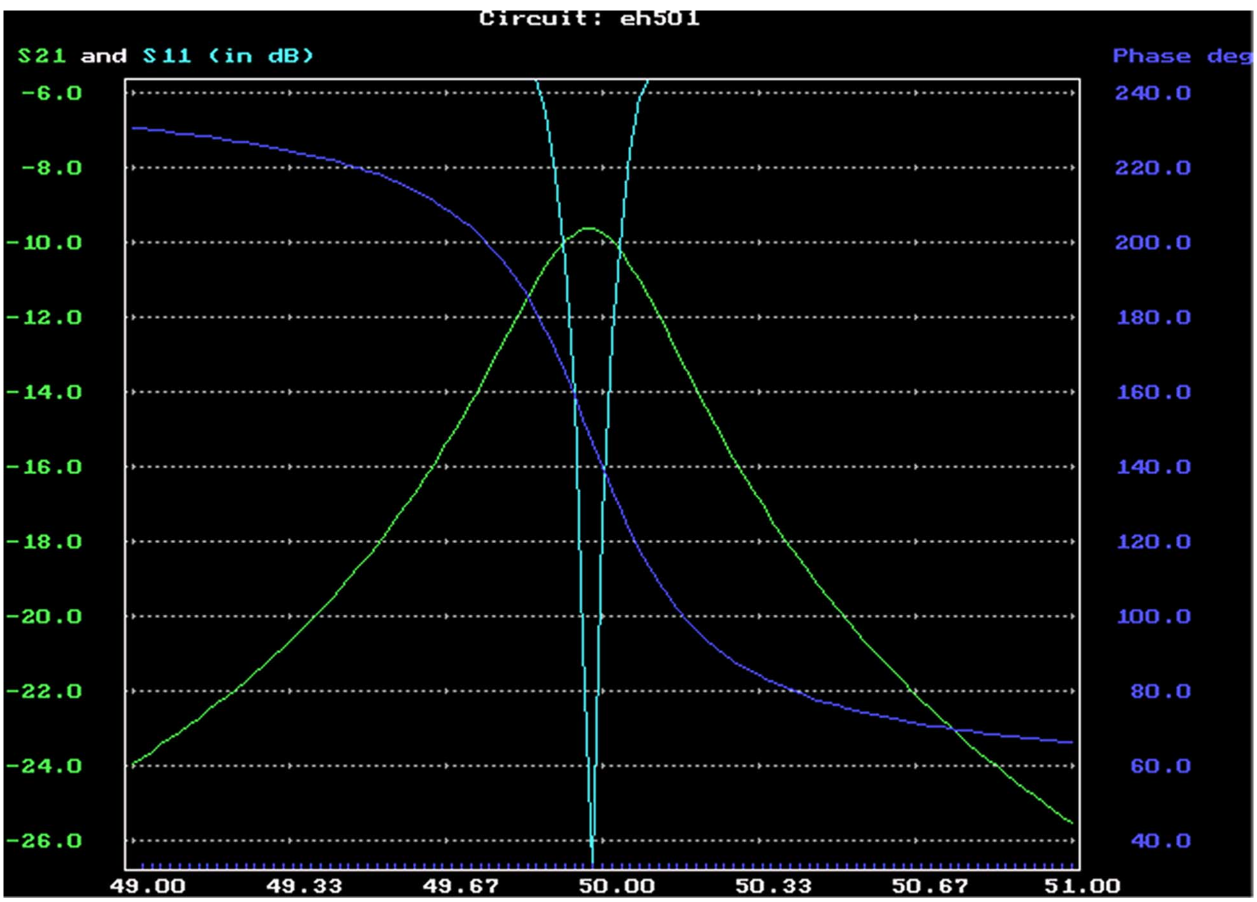

Fig.4. Transfer Function – Return Loss and Phase of one Hertzian antenna with Rr = 0,3 Ohm –Phase 180° at resonance.

Fig. 4a Efficiency as function of Loss in dB.

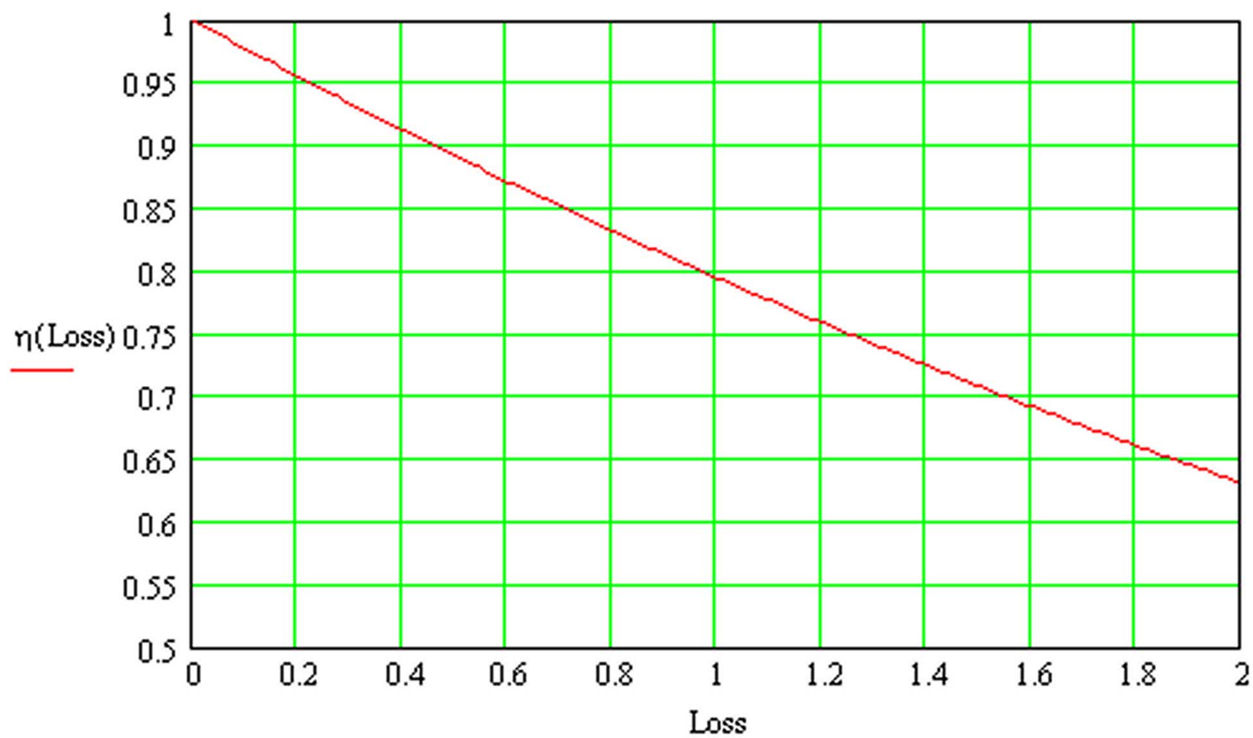

Fig. 4b Efficiency as function of Loss in dB (expanded scale).

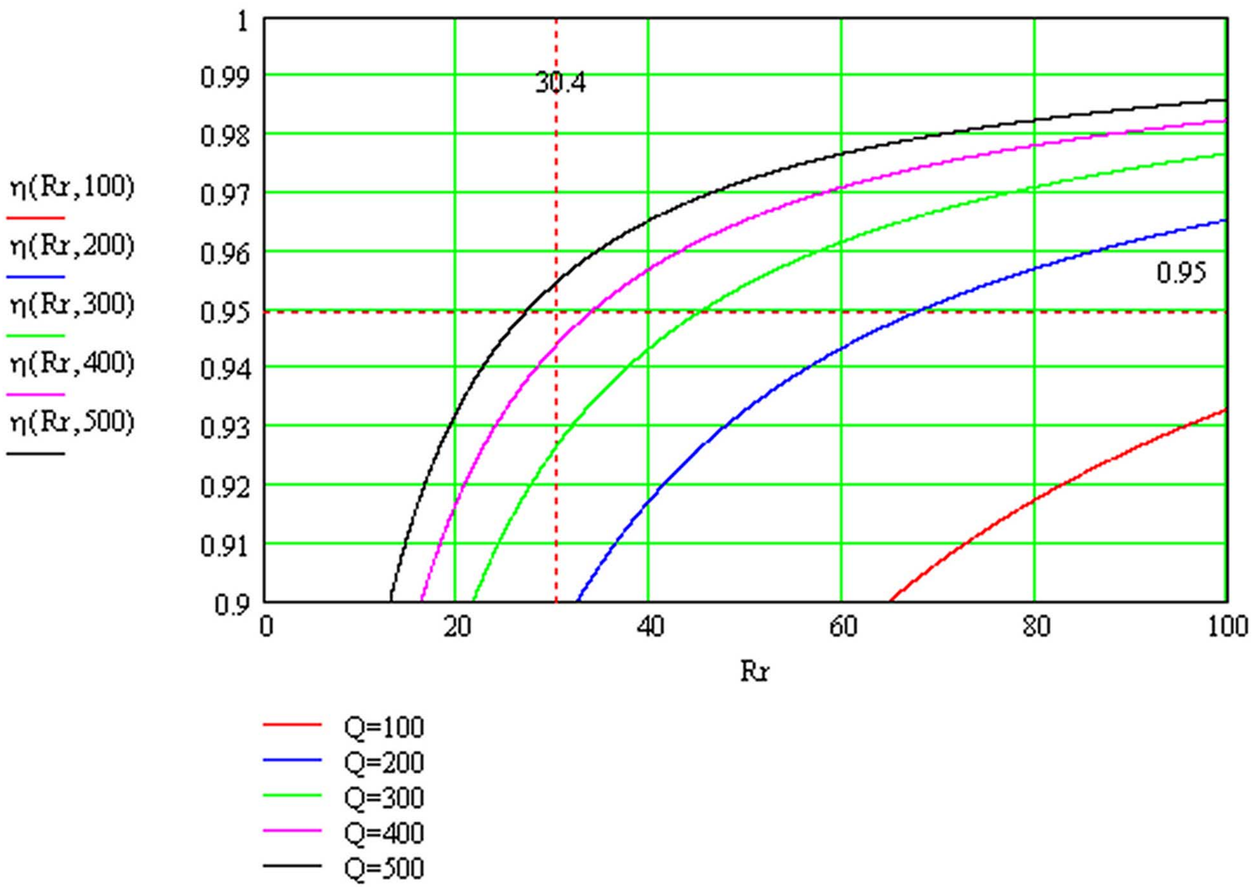

Fig. 4c Efficiency of short capacitive antennas, inductively loaded as functions or Rr for various Q of Ls.

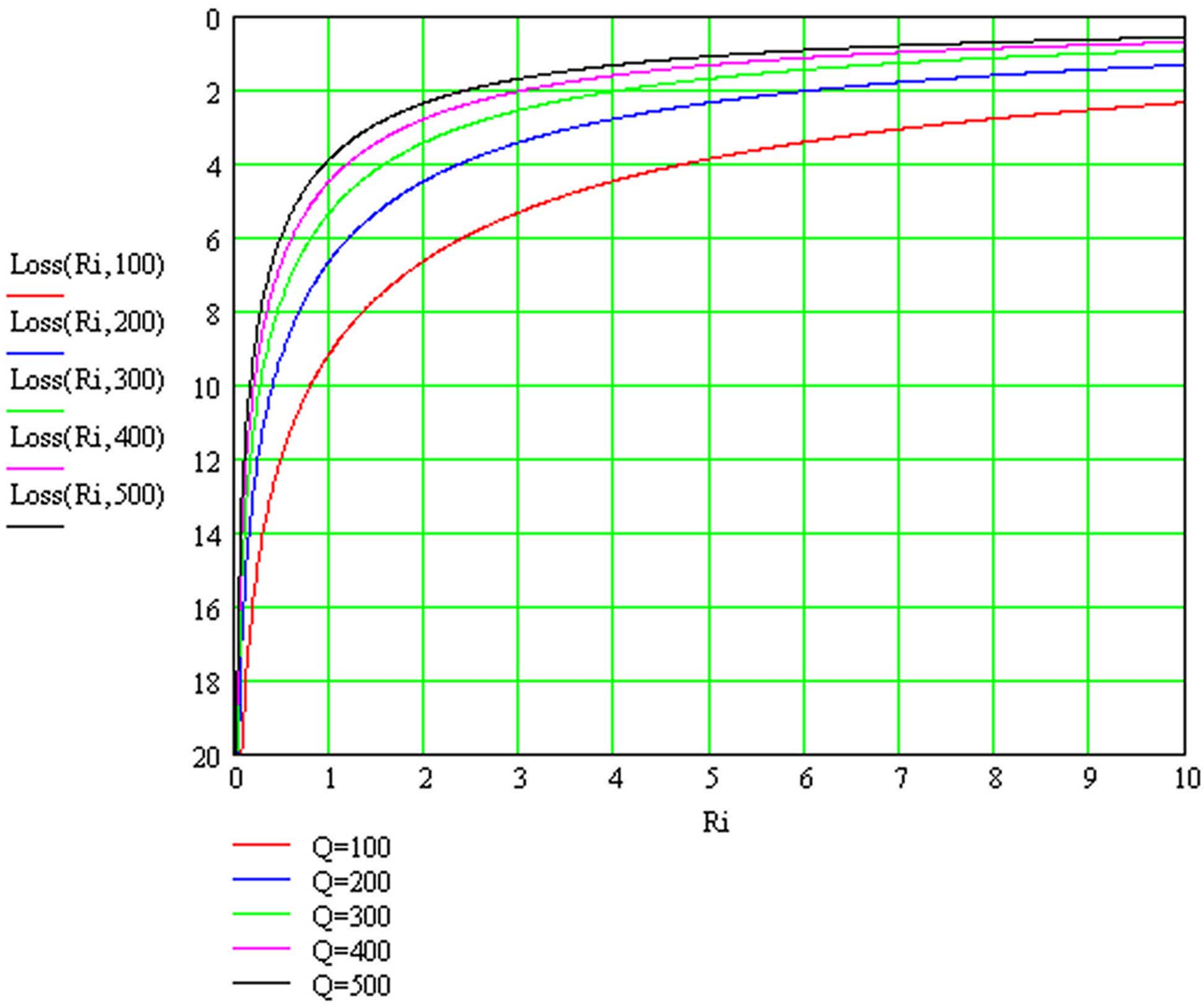

Fig. 4d Loss of short capacitive antennas, inductively loaded as functions or Rr for various Q of Ls.

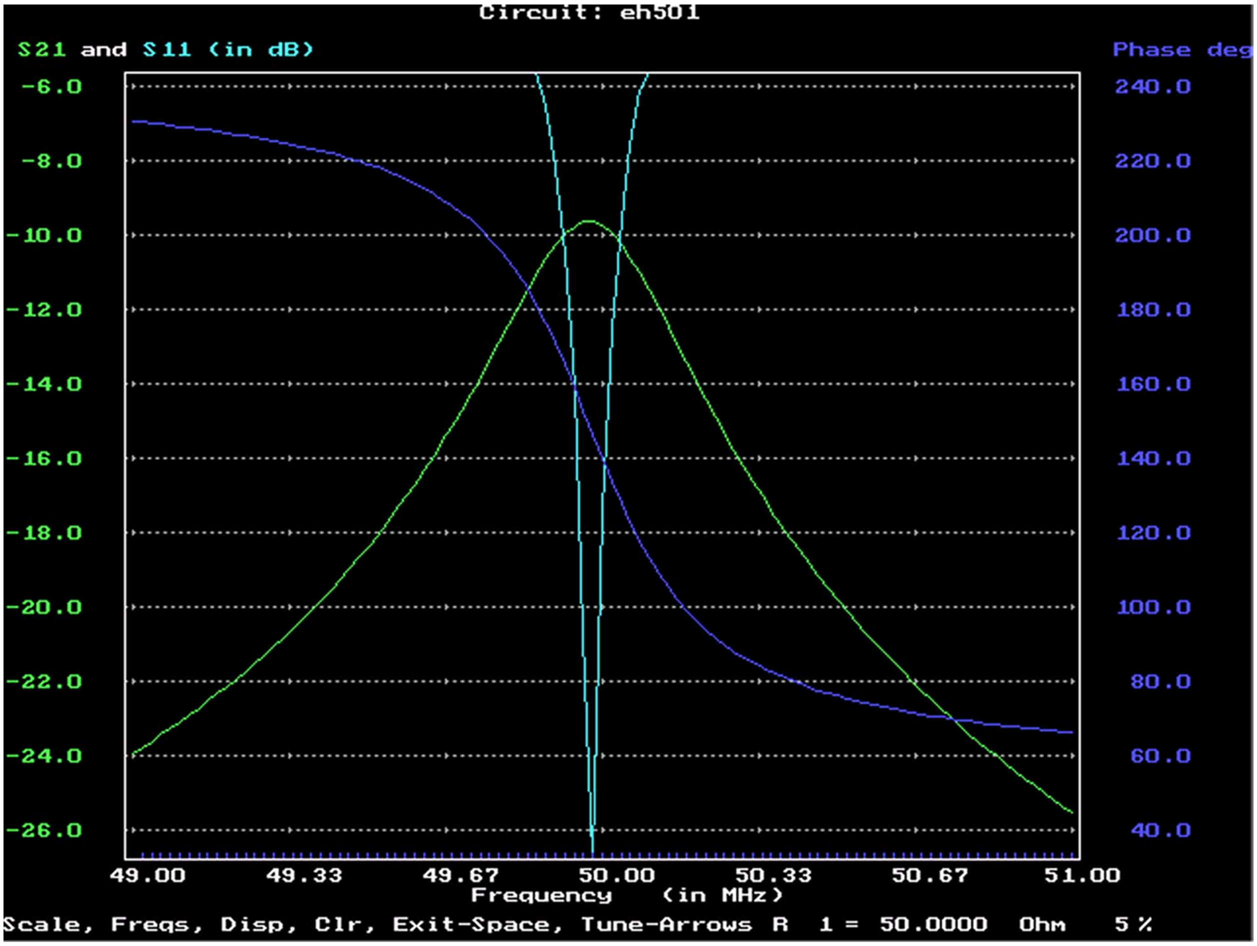

Fig.3. Transfer Function – Return Loss and Phase of one Hertzian antenna with Rr = 0,3 Ohm.

The second simulation was made with Rr = 0.3 Ohm. I tried to return to the same RL by changing the minimum of the values. This was achieved only by changing L1 from 0.15 to 0.22 μH. See **Fig. 3** and **Table 1**, with values of Loss, Q, Efficiency and Phase.

The third simulation was to change the minimum of components to have 180° at resonance. This was achieved with L1 = 0.25 μH and C1 = 52 pF, with no change on Q, RL and Loss. See **Fig. 4** and **Table 1.**

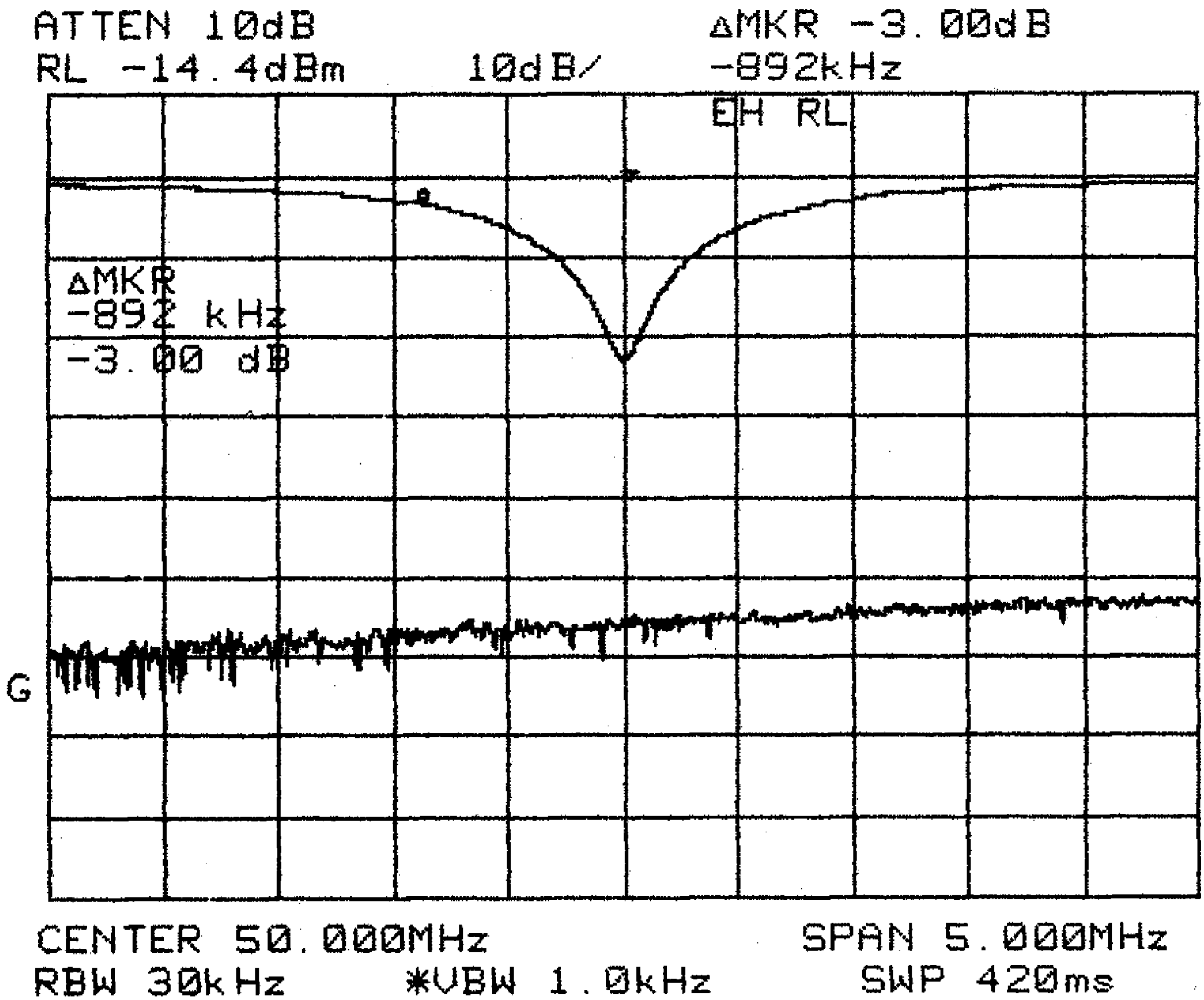

Fig. 5 RETURN LOSS OF EH BICONE – LOWER TRACE LOAD

PRELIMINARY CONCLUSIONS BASED ON NETWORK CALCULATIONS

1) The calculations of efficiency of the network proposed at the EH site, even with very high Q of the main coil (Ls), exclude the possibility of an efficiency equal or better than 95 %.

2) If you can only measure the RL (or WSVR), at resonance, you can have the same value with Rr = 8 or 0,3 Ohm, only by changing the value of L1 (0.15 µH), the little coil of the matching network, by less than 50% (0.22µH).

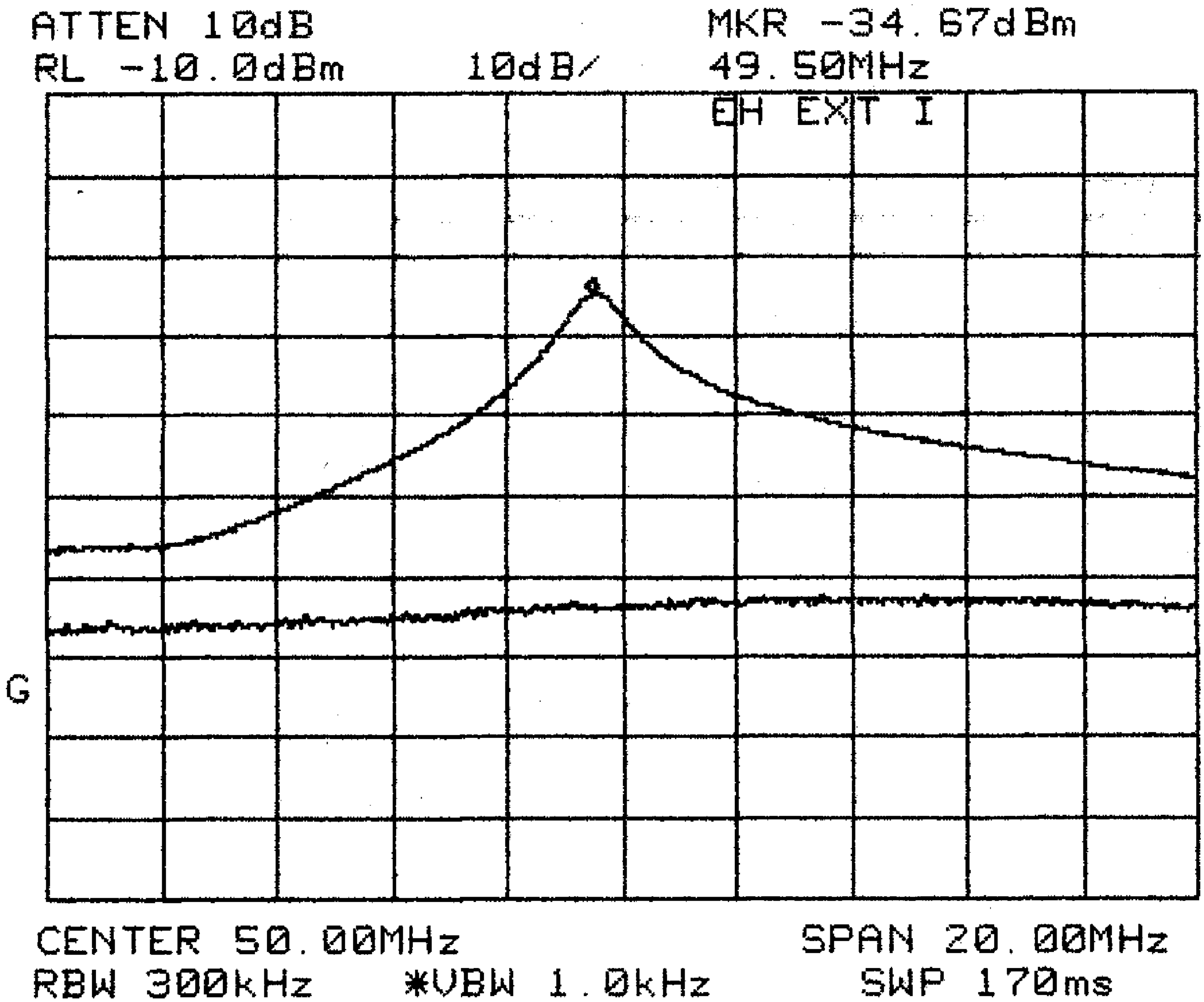

Fig. 6. EXTERNAL COAXIAL CABLE CURRENTS OF EH BICONE – LOWER TRACE LOAD

ANTENNA MEASUREMENTS

I built a bicone EH antenna with the values of **Fig. 1** and **Table 1**. All the values were checked with the Marconi TF1245A Q-meter. The values of RL and Q were very dependent on the position of the coaxial cable relative to other objects. This clearly indicates that RF currents are flowing on the shield of the coaxial cable that radiates and is hence part of the antenna.

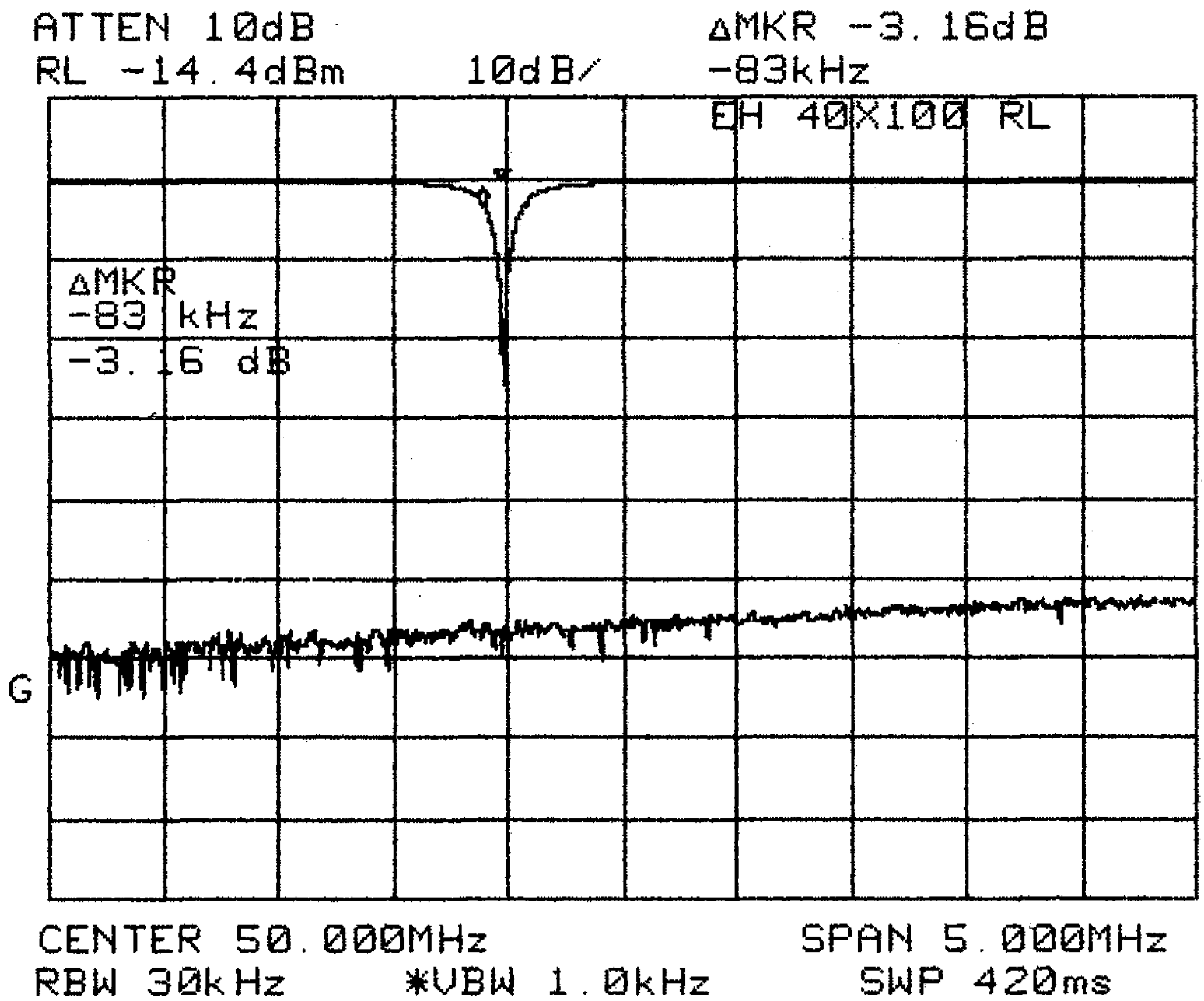

Fig. 7. RETURN LOSS EH WITH GP 40X100 CM

To measure the external current, I built a tool consisting of a RF current transformer: a toroidal core with an E shielded link connected to a BNC connector. The coaxial cable passes through the toroid. Values of RL and I (external current) of the cable at the base of the antenna are plotted in **Fig. 5** and **Fig. 6**. Lower traces are the values connecting a load instead of the antenna.

To further validate the concept that the cable radiates and is part of the antenna, I put under the upper cone a metallic ground plane of 40x100 cm. Results are plotted in **Fig. 7** and **Fig. 8**. External currents are reduced by several dB and the Q increases because the radiation from the cable is reduced.

Stefano Galastri and Marco Menozzi supplied two other EH antennas made by them with a "Lattice Network." I have supplied the measurements of only one of them because the coils of the first melted during mere practical efficiency tests (100 W CW). These coils were made with trefold copper wire with plastic insulation. Only less than a couple of dB of gain difference was in any way measured during preliminary tests. The two antennas have big differences in the L/D of the dipoles.

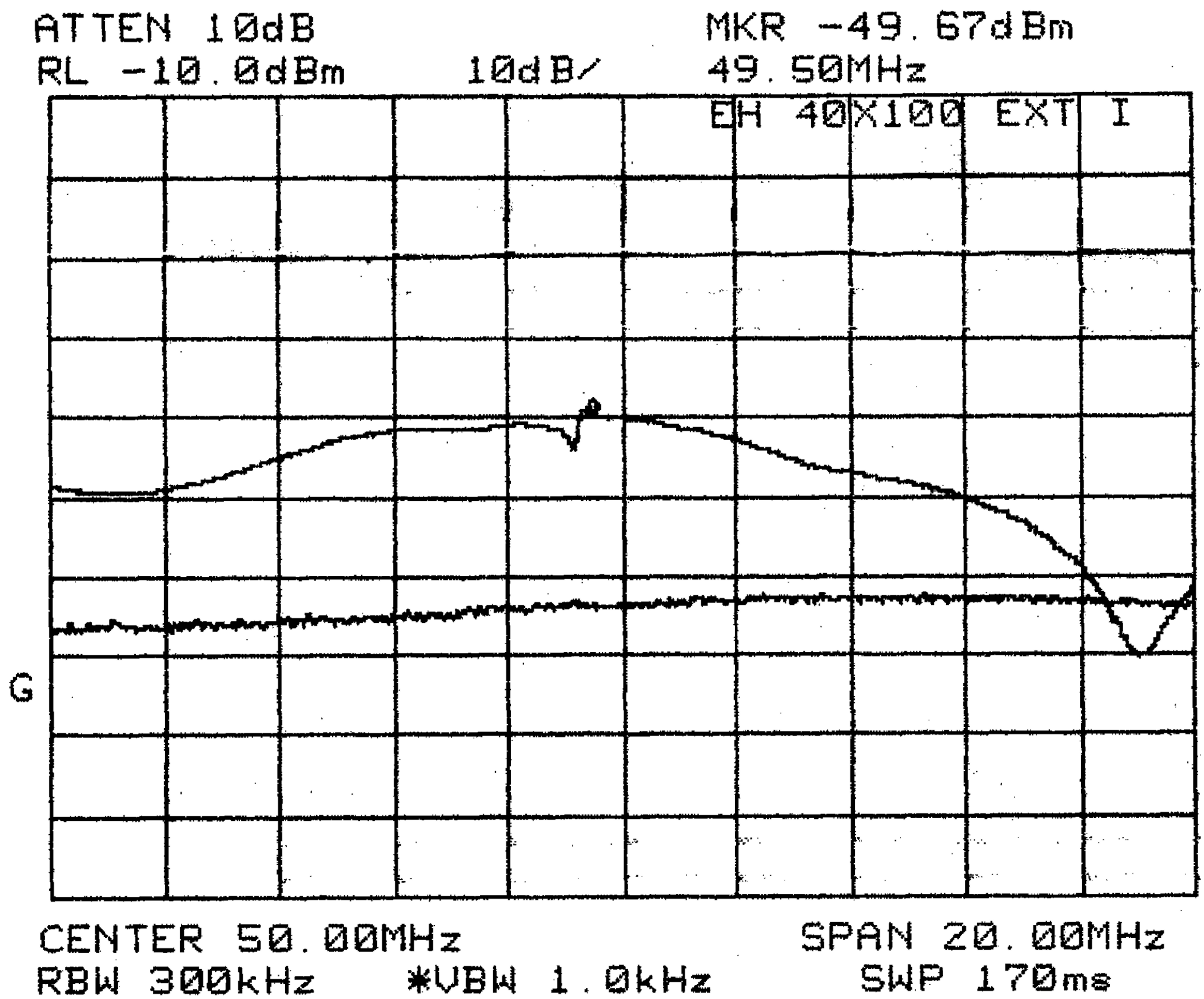

Fig. 8. EXTERNAL CURRENTS OF EH WITH GP 40X100 CM

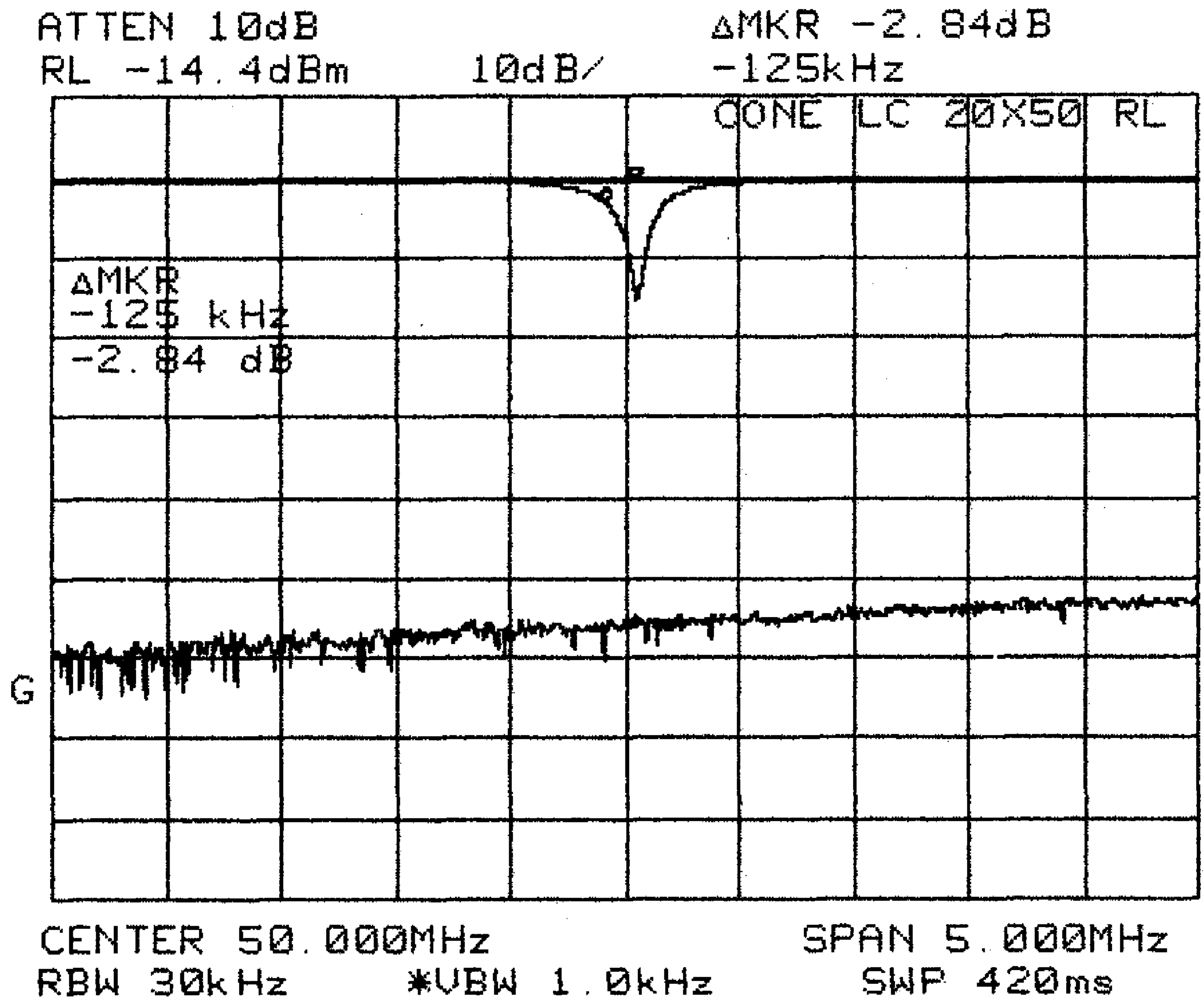

Fig.9. RETURN LOSS CONE LC NETWORK GROUND PLANE 20X50 CM

Other measurements were carried out with the same cone mounted on metallic ground planes of 20x50 and 40x100 cm (**Fig. 9, 10, 11, 12**). The network consisted now of a simple LC. Part of the L resonates the capacitive part of the antenna and part works in the matching network. As the ground plane surface increases, the external current becomes lower and the Q increases.

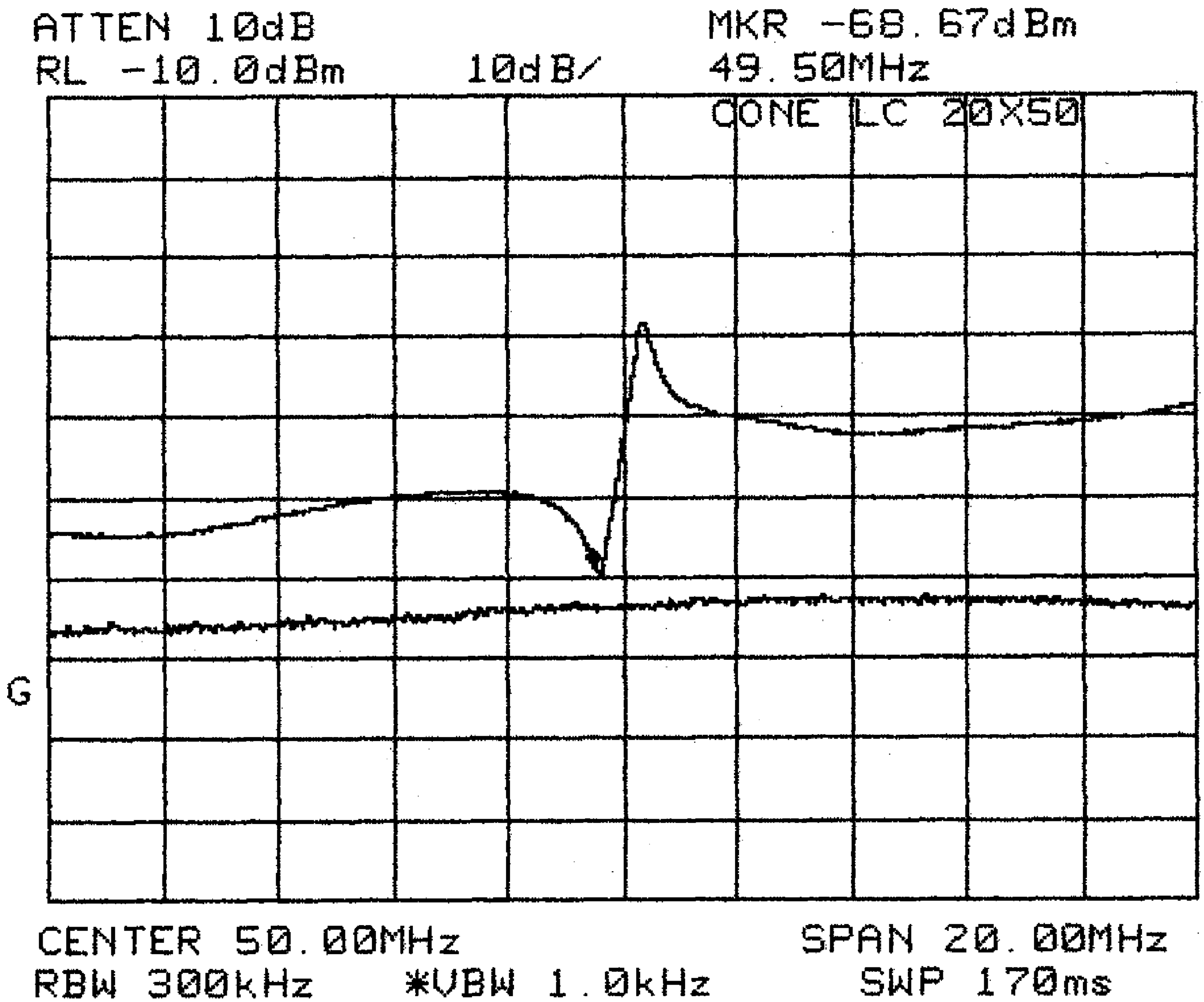

Fig. 10. EXTERNAL CURRENTS CONE LC NETWORK GROUND PLANE 20X50 CM

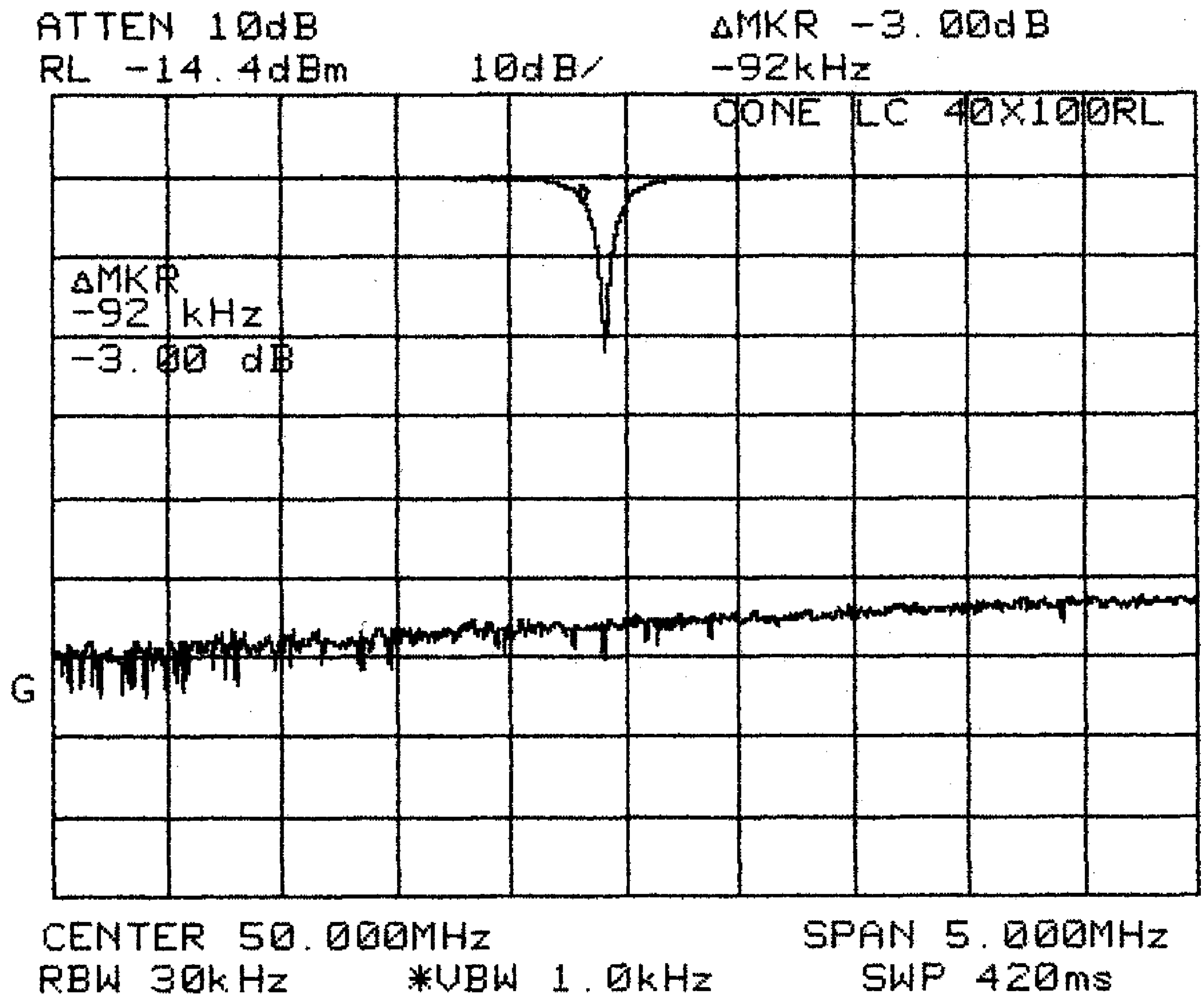

Fig. 11. EXTERNAL CURRENTS CONE LC NETWORK GROUND PLANE 40X100 CM

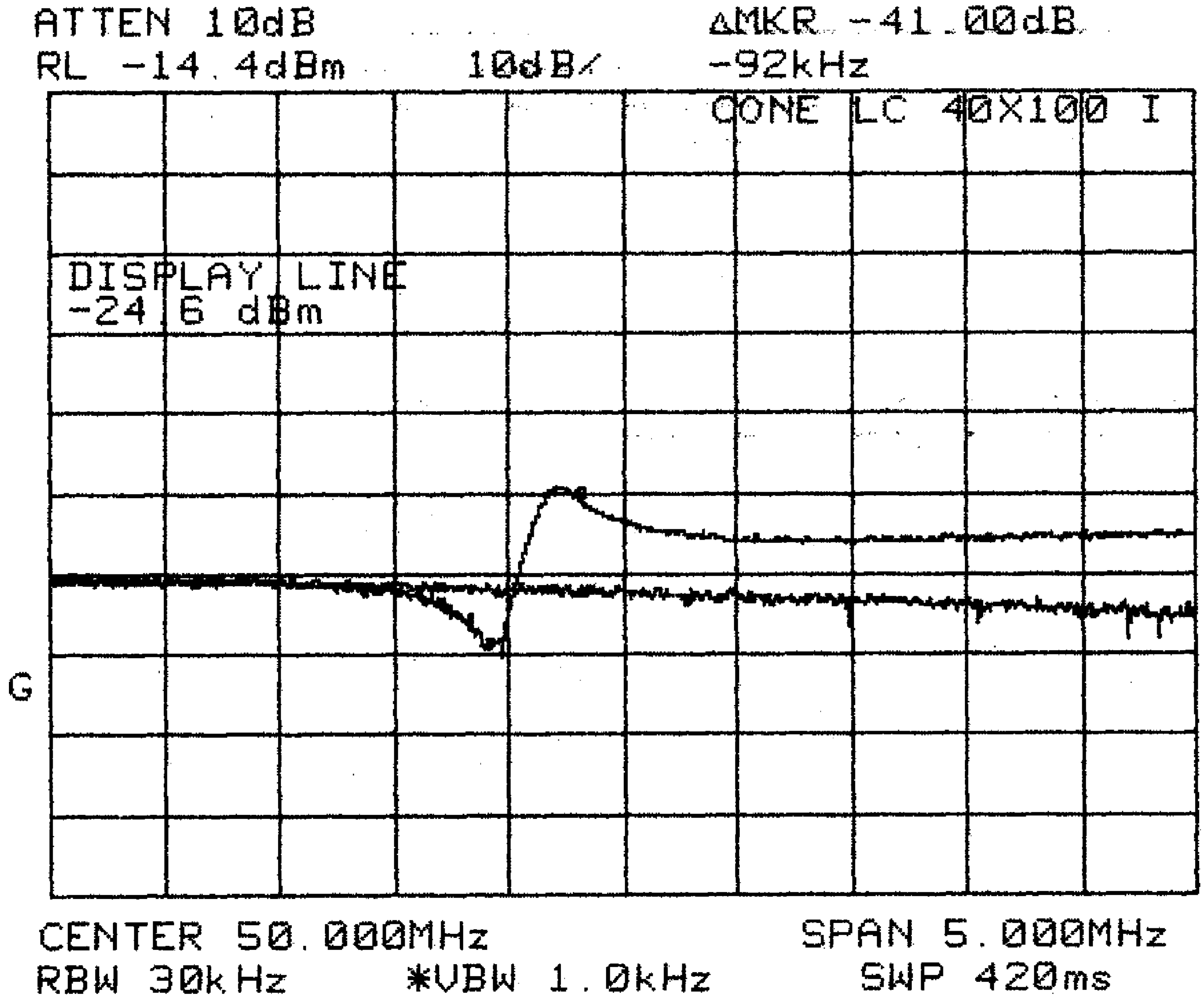

Fig. 12. EXTERNAL CURRENTS CONE LC NETWORK GROUND PLANE 40X100 CM

Other measurements were carried out on an aluminium Loop of 30 cm of diameter and on one of the reference Ground Planes (**Fig. 13, 14, 15, 16**). The measurements of the Loop are similar to those of the cone with ground planes. On the other hand, small-resonated loop (inductive) are complements to short (capacitive) resonated antennas. The GP exhibited, of course, the minimum Q (non measurable, because the bandwidth is outside the sweep), and limited external currents on the cable shield. Results are summarised in **Table 2**.

Description	Fig.	RL	B	Q	Imax	Imin	Imed	Iref	Deltal1	Deltal2
					In Pass Band	In Pass Band	In Pass Band	Load	Load	EH
		dB	MHz		dB	dB	dB	dB	dB	dB
EH LT	5 - 6	22	1,784	28	-34,7	-53	-43,9	-73	29,2	0
EH LT GP 40x100 cm	7 - 8	25	0,166	301,2	-49,7	-54	-51,9	-73	21,2	-8
Cone LC GP 20x50 cm	9 - 10	15	0,25	200	-38	-70	-54	-73	19	-10,1
Cone LC GP 40x100 cm	11 - 12	22	0,184	271,7	-59	-65	-62	-73	11	-18,1
Loop Alluminium D = 30 cm	13 - 14	10	0,416	120,2	-55	-74	-64,5	-73	8,5	-20,6
GP	15 - 16	15	--	--	-65	-79	-72	-73	1	-28,1
EH Lattice	17-18	20	1,916	26	-38	-48	-43	-73	30	0,8

Table 2

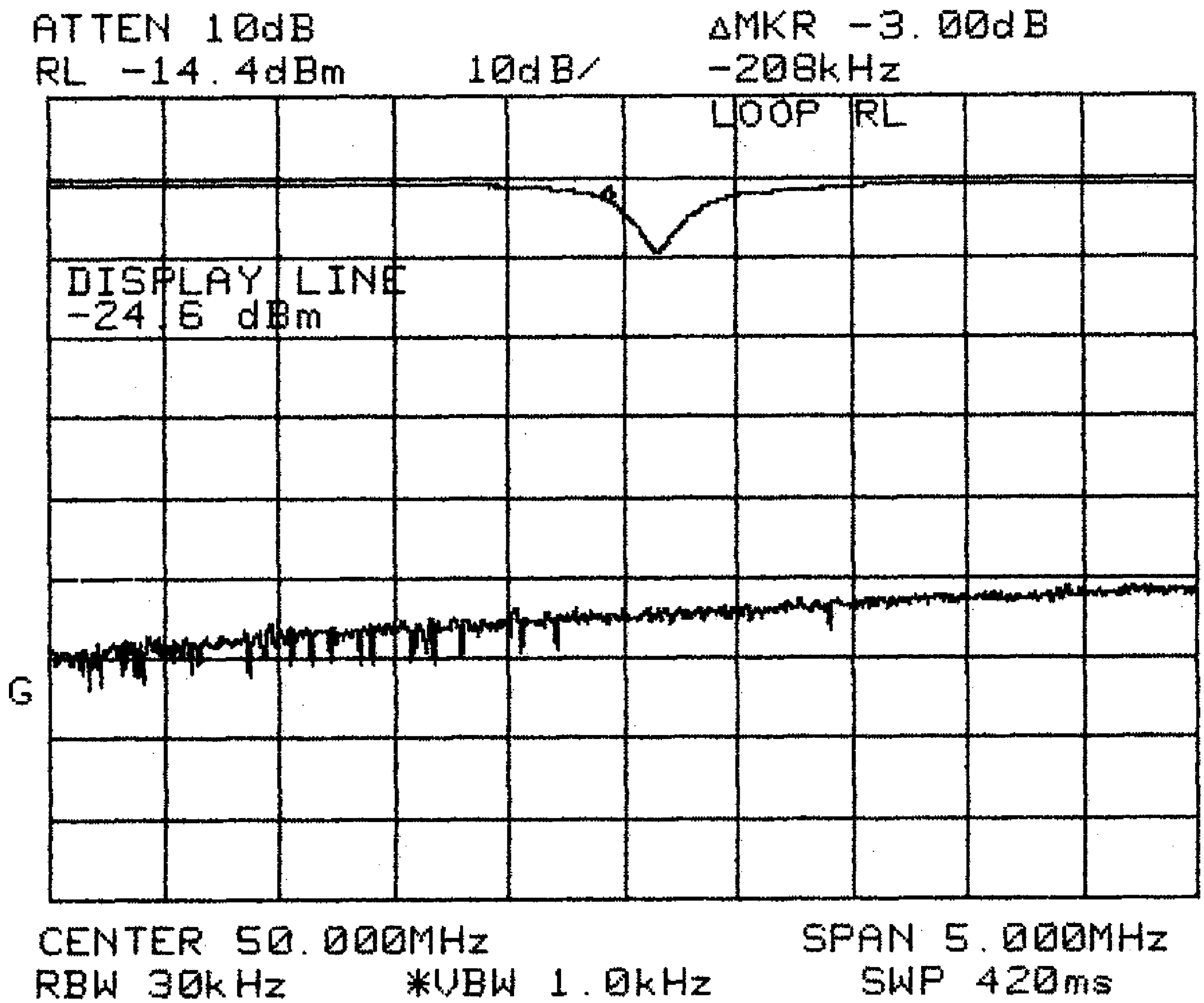

Fig.13. RETURN LOSS LOOP D = 30 CM

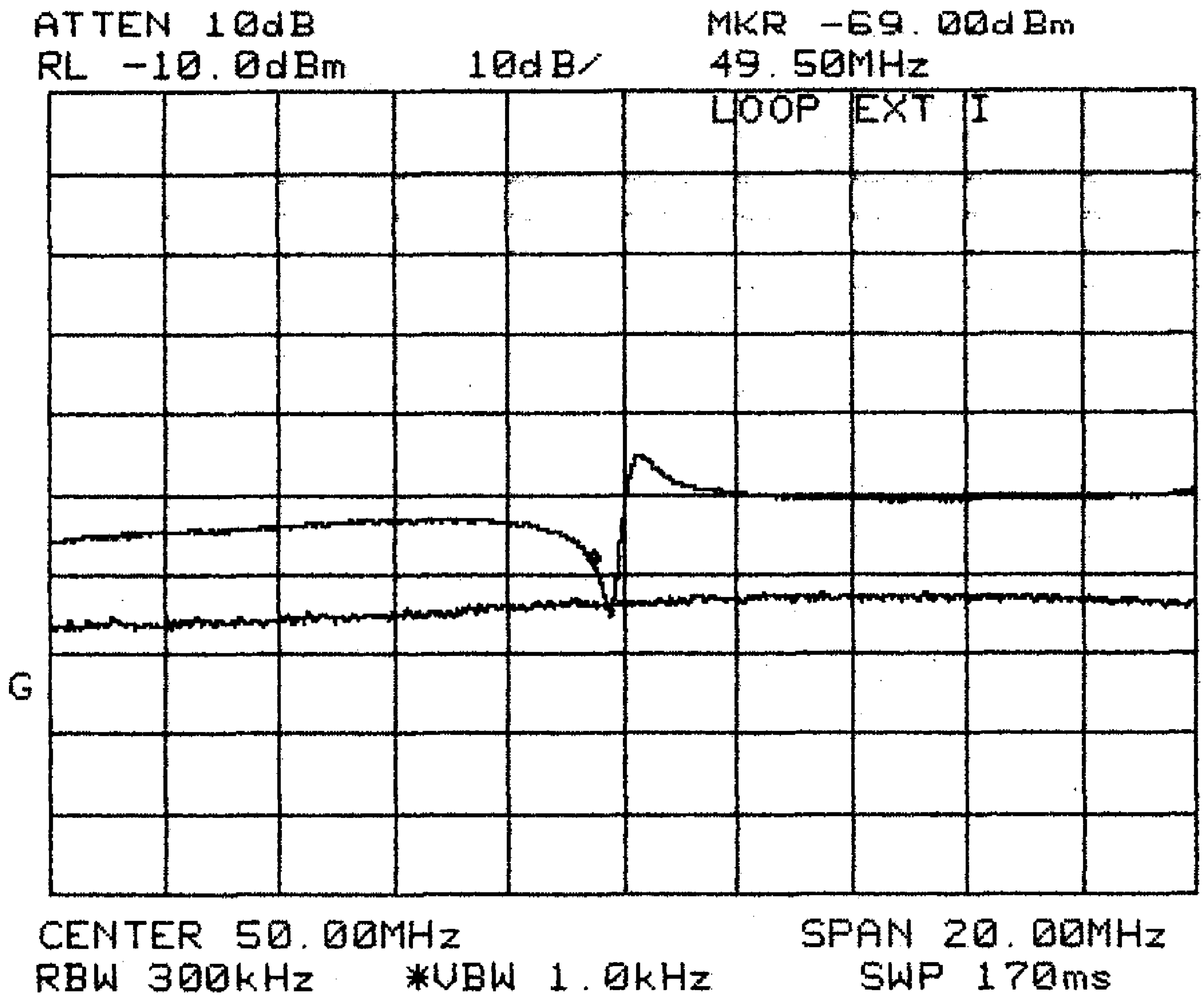

Fig. 14. EXTERNAL CURRENTS LOOP D = 30 CM

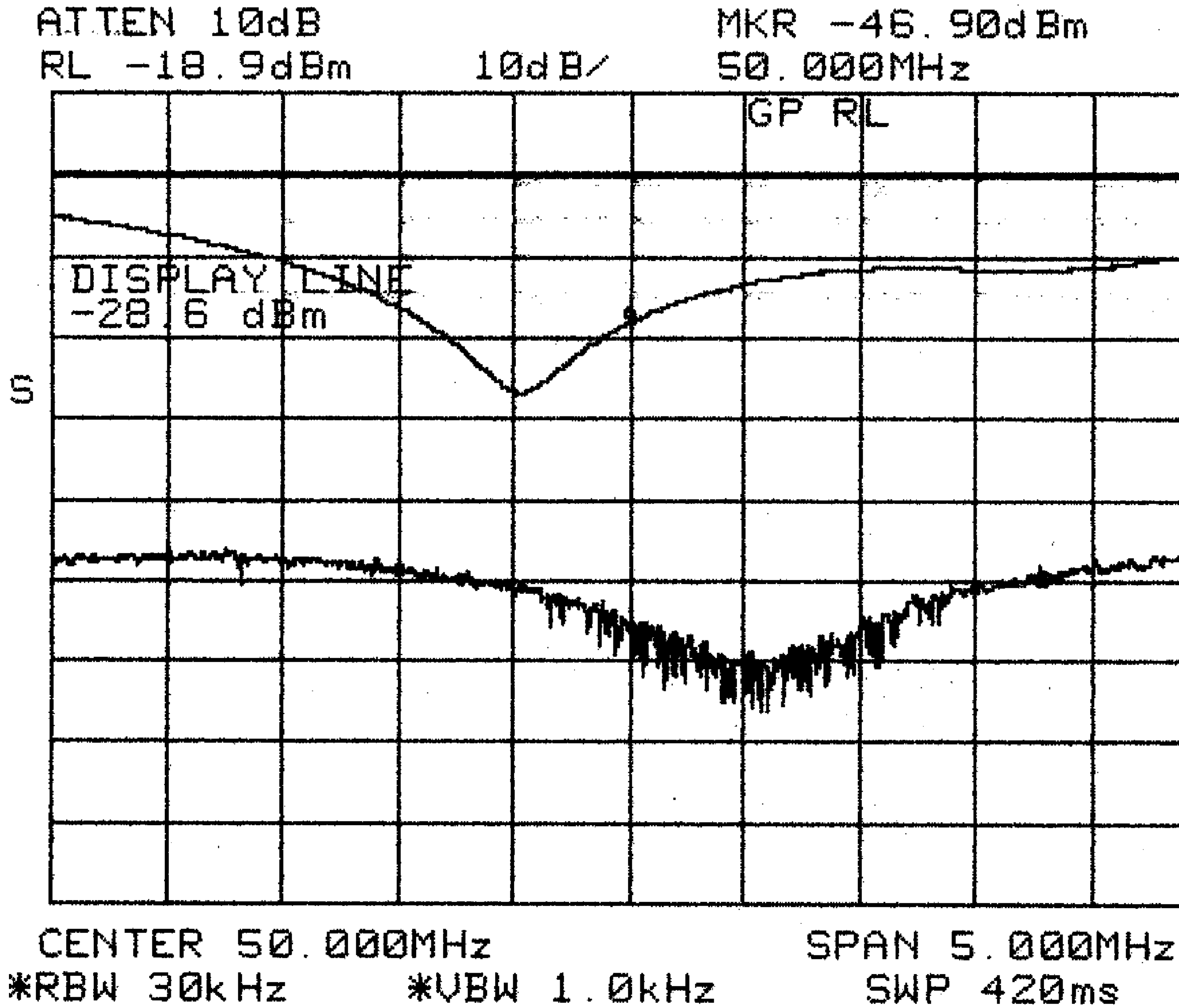

Fig. 15. RETURN LOSS REFERENCE GROUND PLANE 3 RADIALS

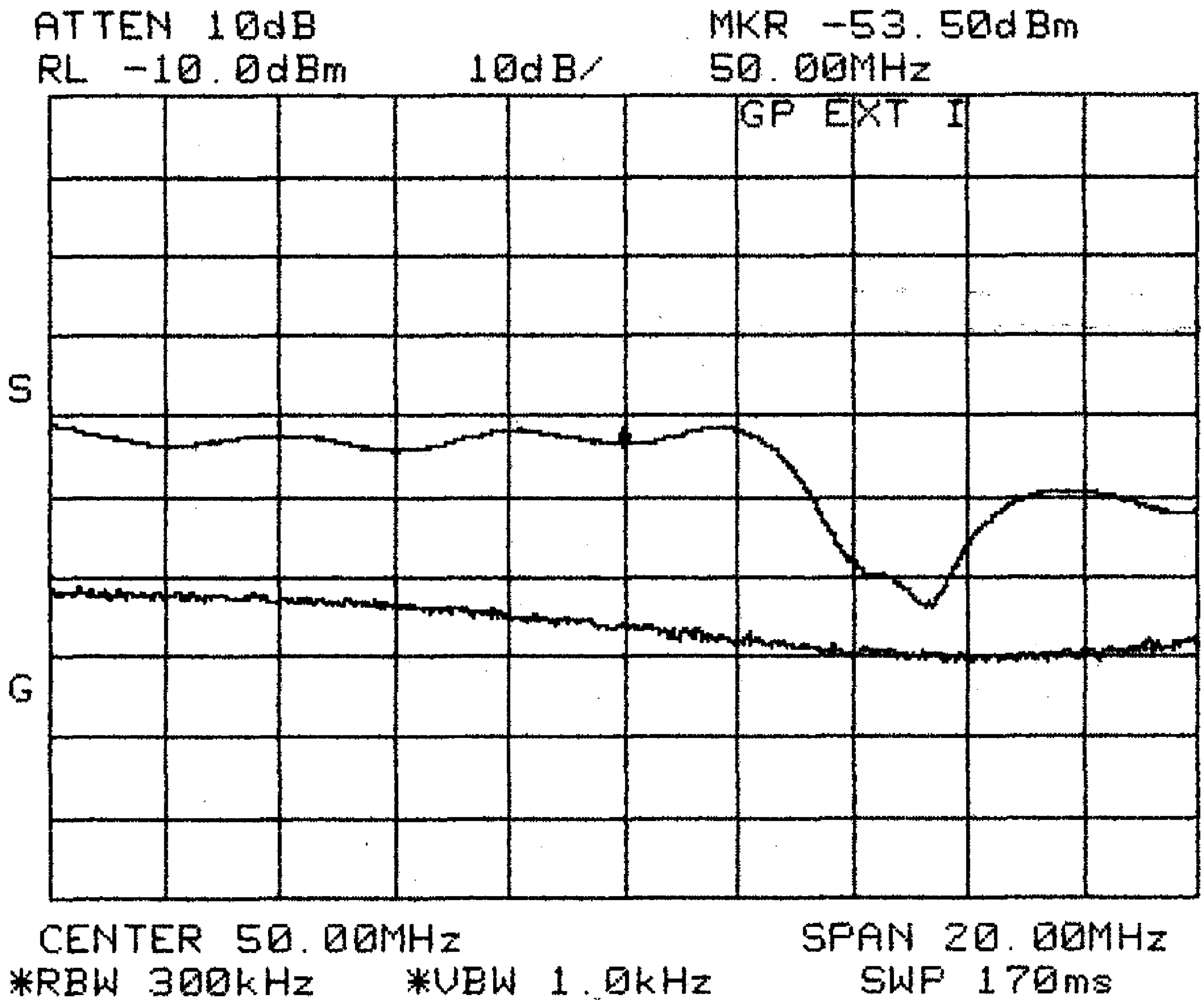

FIG. 16. EXTERNAL CURRENTS REFERENCE GROUND PLANE 3 RADIALS

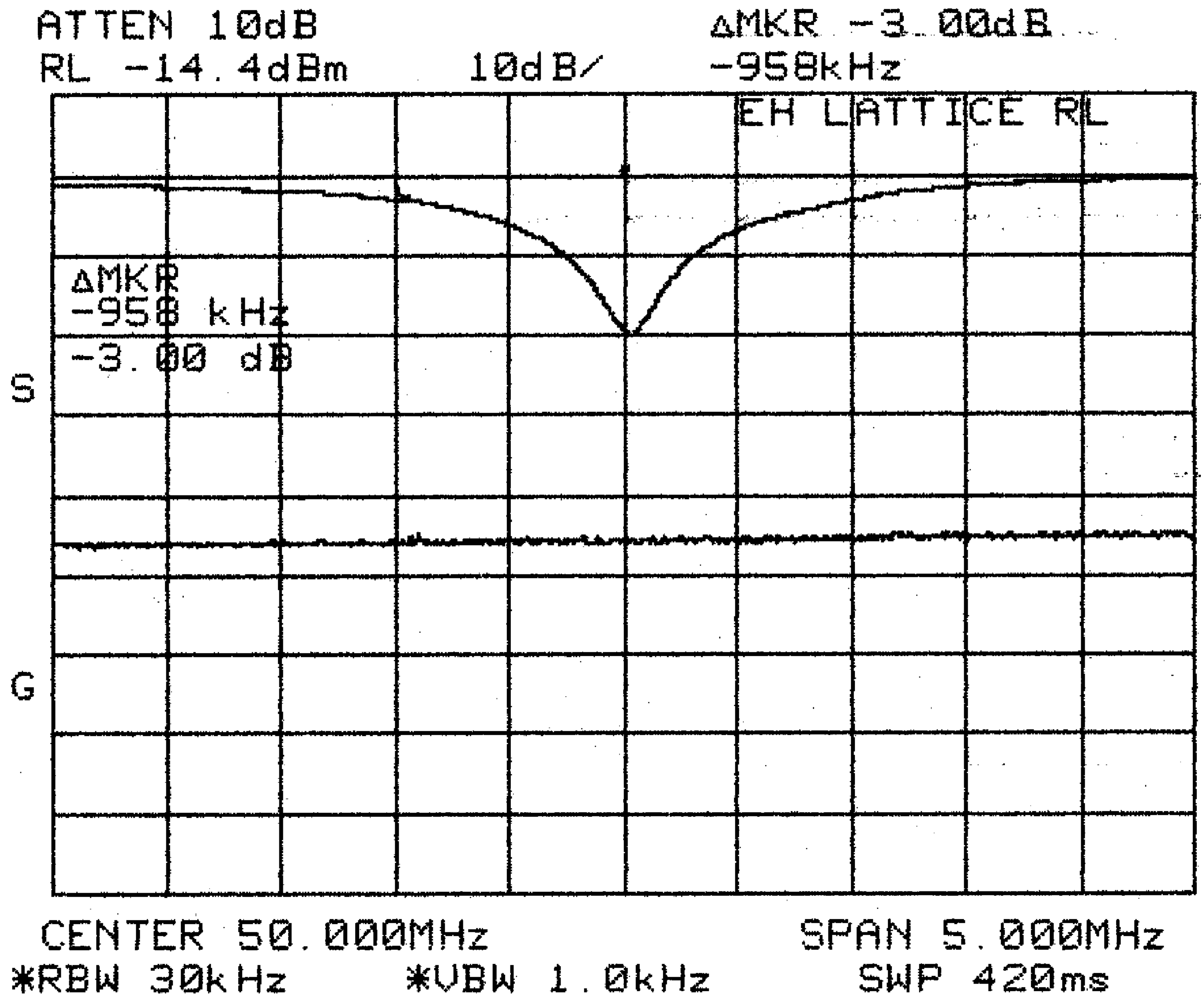

Fig. 17. RETURN LOSS EH DIPOLE LATTICE NETWORK

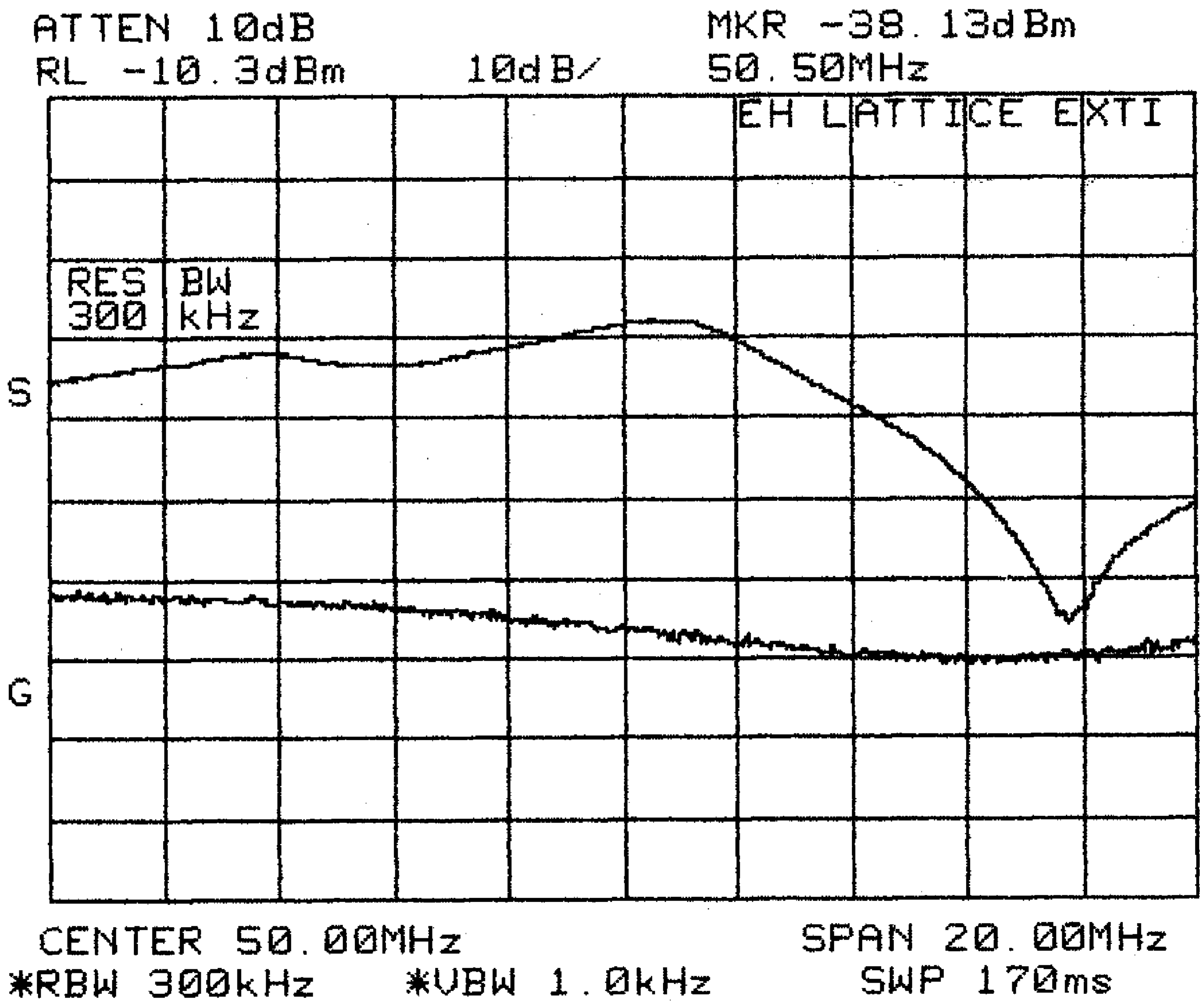

Fig. 18. EXTERNAL CURRENTS EH DIPOLE LATTICE NETWORK

Coming up in Part 2

RELATIVE GAIN MEASUREMENTS IN AN OPEN FIELD CONTROLLED TEST RANGE

After the matching and external current measurement phase of all the EH antennas, it was time for Claudio to get started with the relative gain measurements in an open field controlled test range. This is where we pick up in ***Testing the EH Antenna: Part 2*** in the next issue of *antenneX* - and read about the final conclusions reached by Claudio's about the viability of the EH and its prospects as a compact. ***See you here next month!*** **-30-**

BRIEF BIOGRAPHY OF THE AUTHOR

Claudio Re, I1RFQ is a graduate of Polytecnic of Turin in 1980 with specialization in "Telecommunications and Hyperfrequencies". He is an owner of *Sistel SRL* and *Sinfotel SRL*, two small telecommunications, companies in Italy. He is also a consultant and the Network Director of the World Family of *Radio Maria*, a Catholic Broadcasting Network that broadcasts now in 27 different countries of the globe.

He has experimented with all kinds of equipment from 136 KHz to the optical frequencies (one-way communications at 22km)

Claudio was born in 1956, built his first crystal set receiver at age 6 and at 16, obtained his license with the callsign 1IRFQ.

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