

ELECTRIC AND MAGNETIC FIELD MEASUREMENTS ON BOARD A SHIP

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Abstract: *This paper presents the results of research conducted on board a ship at a customer's request. The devices used during the experimentation, the values obtained and the entailing conclusions will be presented. Measurements were taken over a period of one year.*

Keywords: modulator, power sensor, electric field

1. INTRODUCTION

In order to achieve electromagnetic field measurements on board the ship points of radiation increased concentration were selected. Within each point, background measurements as well as measurements by help of different broadcasting stations located in various frequency ranges and operating modes were conducted. [1, 2, 3]

The gauging instruments that were used to carry out field measurements are hereby presented. The following equipment was used for the taking measurements: R&S FSP13, Spectrum analyzer 9 kHz - 13 GHz, -140 - +30 dBm, RBW 10 Hz - 10 MHz, TFT color display; R&S FSP-B1, Rugged case with variable carrying handle for all FSP models; R&S FSP-B16, LAN interface 10/100 base T for FSP with Nr.1164.4391.XX; R&S FSP-B9, Tracking generator for FSP, 9 kHz - 3 GHz, I/Q; modulator; R&S FSP-B28, Trigger port for FSP; for indication of trigger conditions (necessary for operation with TS-EMF); R&S FSP-B30, DC power supply 12 - 28 V for FSP spectrum analyzer and ESPI test receiver; R&S FSP-B31 NiMH battery pack + charger for FSP, requires FSP-B1 and FSP-B30; R&S FS-K9 Measurements with NRP power sensors NRP-Z11 / Z21 / Z22 / Z23 / Z24 / Z51 / Z55 / Z91 requires NRP-Z3 or NRP-Z4 and specialized software.

The measurement configuration is shown in Figure 1 below.

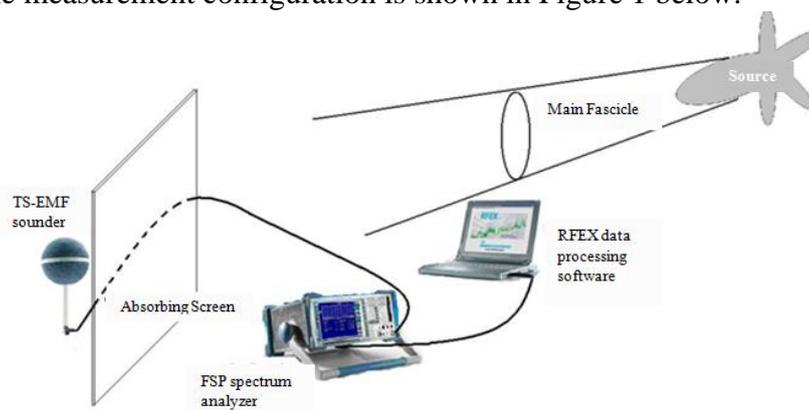


Fig. 1. Measurement Components

Ship measurements aimed at the following frequency ranges, limited by measuring sensor available: 88-200 MHz 200-2200 MHz.

2. DATA COLLECTED FOLLOWING MEASUREMENTS.

On board measurements aimed at collecting data on: the electric field - E [V/m] for different frequency ranges; the electric field [dB μ V/m], the exposure rate; ER: E²/L²; the intensity field limit; the measurement error-ER*1000[%]; the electromagnetic power flux density, PD (or S), [μ W/cm²]; the total field strength (RMS) [V/m], the maximum singular value [V/m]. [4, 5]

For each set of measurements the initial background value of the (electric) field strength was also indicated. For the magnetic field, data are proportionally smaller by Z₀ times in the free space, where Z₀ is the wave impedance in the free space.

The designed Poynting vector gives the power density $S = E \times H = \epsilon_0 E^2 / c$
 where: $\epsilon_0 = 8,85 \times 10^{-12}$ F/m ; $c = 3 \times 10^8$ m/s.

Background Measurements

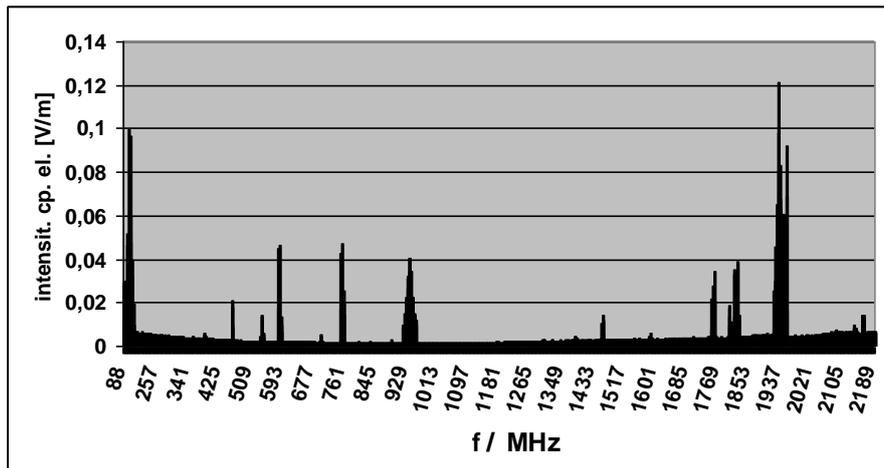


Fig 2. Measurement of Ambient Noise on Heliport Deck

Table 1. Main Measured Corresponding Values

Frequency [MHz]	Electric field strength E [V/m]	Electric field level [dB μ V/m]	Power density [W/m ²]	Power density [μ W/cm ²]
98.0000	0.0515	94.2412	7.0433	0.0007
104.0000	0.0999	99.9934	26.4851	0.0026
105.0000	0.0967	99.7054	24.7858	0.0025
106.0000	0.0599	95.5432	9.5057	0.0010
1935.0000	0.0649	96.2420	11.1650	0.0011
1936.0000	0.0585	95.3412	9.0736	0.0009

Frequency [MHz]	Electric field strength E [V/m]	Electric field level [dB μ V/m]	Power density [W/m ²]	Power density [μ W/cm ²]
1937.0000	0.0586	95.3534	9.0991	0.0009
1938.0000	0.0808	98.1507	17.3273	0.0017
1939.0000	0.1214	101.6821	39.0726	0.0039
1940.0000	0.0982	99.8422	25.5785	0.0026
1941.0000	0.0528	94.4592	7.4059	0.0007
1942.0000	0.0560	94.9649	8.3204	0.0008
1943.0000	0.0638	96.0973	10.7992	0.0011
1944.0000	0.0832	98.3973	18.3394	0.0018
1945.0000	0.0672	96.5458	11.9741	0.0012
1951.0000	0,0604	95.6247	9.6857	0.0010
1953.0000	0.0577	95.2269	8.8378	0.0009
1958.0000	0.0589	95.3954	9.1875	0.0009
1959.0000	0.0923	99.3076	22.6162	0.0023
1960.0000	0.0688	96.7558	12.5673	0.0013
overall exposure rate			565.2040	0.0565
total intensity of electrical capacity (RMS)	0.4616			
maximum measured value	0.1214			

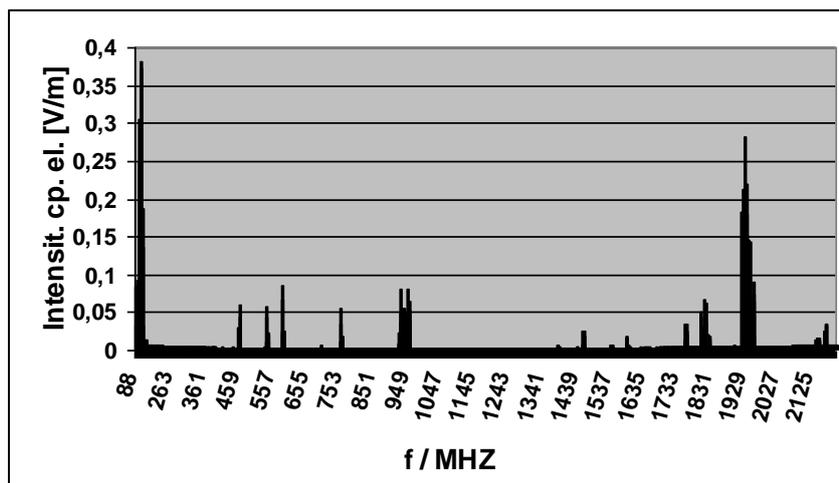


Fig 3. Measurement of ambient noise on the bridge deck

Table 2. Main Measured Values

Frequency [MHz]	Electric field strength E [V/m]	Electric field level [dB μ V/m]	Power density [W/m ²]	Power density [μ W/cm ²]	Frequency [MHz]
97.0000	0.2480	107.8891	0.0002	163.1420	0.0163
98.0000	0.3045	109.6707	0.0002	245.8852	0.0246
99.0000	0.1511	103.5879	0.0001	60.5965	0.0061
103.0000	0.1463	103.3041	0.0001	56.7629	0.0057
104.0000	0.3808	111.6140	0.0004	384.6399	0.0385
105.0000	0.3722	111.4149	0.0004	367.4121	0.0367
106.0000	0.1863	105.4039	0.0001	92.0546	0.0092
107.0000	0.1374	102.7570	0.0001	50.0451	0.0050
1925.0000	0.1837	105.2831	0.0001	89.5293	0.0090
1926.0000	0.2123	106.5387	0.0001	119.5442	0.0120
1932.0000	0.1415	103.0121	0.0001	53.0722	0.0053
1933.0000	0.1297	102.2597	0.0000	44.6304	0.0045
1934.0000	0.1575	103.9454	0.0001	65.7958	0.0066
1935.0000	0.2824	109.0184	0.0002	211.5896	0.0212
1936.0000	0.2167	106.7155	0.0001	124.5126	0.0125
1938.0000	0.1809	105.1487	0.0001	86.8017	0.0087
1939.0000	0.2197	106.8384	0.0001	128.0839	0.0128
1940.0000	0.1536	103.7253	0.0001	62.5450	0.0063
1942.0000	0.1454	103.2501	0.0001	56.0621	0.0056
1947.0000	0.1435	103.1357	0.0001	54.6040	0.0055
overall exposure rate			0.0034	3390.6864	0.3391
total intensity of electrical capacity (RMS)	1.130614				
maximum measured value	0.3808				

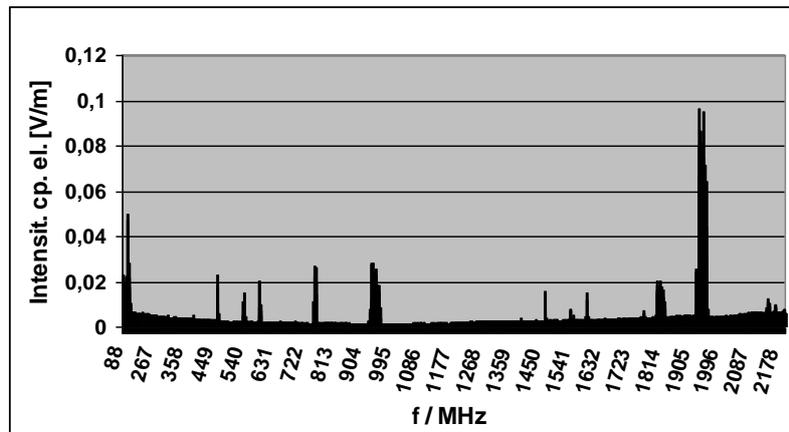


Fig 4. Measurement of ambient noise on the bridge deck (inside)

Table 3. Main Measured Values

Frequency [MHz]	Electric field strength E [V/m]	Electric field level [dB μ V/m]	Power density [W/m ²]	Power density [μ W/cm ²]	Frequency [MHz]
104.0000	0.0496	93.9117	0.0000	6.5287	0.0007
105.0000	0.0475	93.5313	0.0000	5.9813	0.0006
1935.0000	0.0670	96.5181	0.0000	11.8978	0.0012
1936.0000	0.0966	99.6978	0.0000	24.7421	0.0025
1937.0000	0.0803	98.0922	0.0000	17.0952	0.0017
1938.0000	0.0810	98.1683	0.0000	17.3974	0.0017
1939.0000	0.0868	98.7707	0.0000	19.9860	0.0020
1940.0000	0.0662	96.4141	0.0000	11.6164	0.0012
1942.0000	0.0753	97.5313	0.0000	15.0241	0.0015
1943.0000	0.0594	95.4716	0.0000	9.3501	0.0009
1944.0000	0.0614	95.7682	0.0000	10.0111	0.0010
1946.0000	0.0593	95.4608	0.0000	9.3270	0.0009
1947.0000	0.0952	99.5765	0.0000	24.0606	0.0024
1948.0000	0.0749	97.4845	0.0000	14.8629	0.0015
1949.0000	0.0592	95.4487	0.0000	9.3010	0.0009
1950.0000	0.0687	96.7406	0.0000	12.5232	0.0013
1952.0000	0.0462	93.2882	0.0000	5.6556	0.0006
1955.0000	0.0713	97.0581	0.0000	13.4730	0.0013
1956.0000	0.0643	96.1671	0.0000	10.9741	0.0011
1959.0000	0.0438	92.8296	0.0000	5.0888	0.0005
overall exposure rate			0.0004	412.4174	0.0412
total intensity of electrical capacity (RMS)	0.394311				
maximum measured value	0.0966				

Table 4. Main Measured Corresponding Values

Measurement Location	Overall exposure rate	Total intensity of electrical capacity (rms)	Maximum measured value
Heliport deck	0.0565	0.4616	0.1214
Bridge (outside)	0.3391	1.130614	0.3808
Bridge	0.0412	0.394311	0.0966

The above figures and tables show that the measured values increase with the height of the measurement location. Also, the values measured in the bridge, on the inside do not differ much from those measured on the heliport deck on the outside.

Values recorded by help of broadcasting stations in different on board locations

Table 5. Corresponding measured values due to No.1 broadcasting station on 140 MHz (frequency), AM - 100 W at different measurement points

Frequency [MHz]	Electric field strength E [V/m]	Electric field level [dB μ V/m]	Power density [μ W/cm ²]	Measurement Location
138.0000	0.0586	95.3526	0.0095	Artillery deck
139.0000	0.2475	107.8720	0.0108	
140.0000	0.5552	114.8886	0.0115	
141.0000	0.2694	108.6077	0.0109	
142.0000	0.0565	95.0409	0.0095	
138.0000	0.0147	83.3640	0.0095	Heliport deck
139.0000	0.0764	97.6656	0.0108	
140.0000	0.1286	102.1851	0.0115	
141.0000	0.0762	97.6435	0.0109	
142.0000	0.0144	83.1805	0.0095	
138.0000	0.1911	105.6239	0.0106	Bridge (outside)
139.0000	1.0628	120.5288	0.0121	
140.0000	1.6507	124.3531	0.0124	
141.0000	1.0630	120.5303	0.0121	
142.0000	0.2050	106.2334	0.0106	
138.0000	0.0262	88.3614	0.0088	Bridge
139.0000	0.1337	102.5225	0.0103	
140.0000	0.1974	105.9051	0.0106	
141.0000	0.1170	101.3641	0.0101	
142.0000	0.0264	88.4448	0.0088	

Table 6. Corresponding Electrically Measured Values Due to no.1 Broadcasting Station on 240 MHz (frequency), AM – 100 W in different measurement locations

Frequency [MHz]	Electric field strength E [V/m]	Electric field level [dB μ V/m]	Power density [μ W/cm ²]	Measurement Location
238.0000	0.0075	77.5125	0.0078	Heliport deck
239.0000	0.0388	91.7778	0.0092	
240.0000	0.0603	95.6065	0.0096	
241.0000	0.0410	92.2646	0.0092	
242.0000	0.0091	79.1874	0.0079	
238.0000	0.0320	90.1022	0.0090	Bridge (outside)
239.0000	0.1752	104.8723	0.0105	
240.0000	0.2509	107.9893	0.0108	
241.0000	0.1502	103.5358	0.0104	
242.0000	0.0207	86.3391	0.0086	
238.0000	0.0108	80.6997	0.0081	Bridge
239.0000	0.0598	95.5286	0.0096	
240.0000	0.0923	99.3085	0.0099	
241.0000	0.0621	95.8562	0.0096	
242.0000	0.0132	82.3999	0.0082	

The two graphs and tables reveal that the values of the electric field strength decrease with the distance from the transmitting antenna. It also should be noted that the values of the electric field intensity on the heliport deck, in the open, are smaller than the values measured on the bridge in confinement. This was also noticed during the measurements with US type NARDA 8718 model 1507 series meter and with sounders in the 300 kHz - 50GHz frequency range.

3. CONCLUSIONS

From the analysis the following conclusions can be drawn:

- the electric field strength decreases with the distance from the transmitting antenna and increases with the height of the measurement location;
- the values of the electric field strength measured in the background measurement decrease in the following order: outside the bridge deck, inside the bridge, on the heliport deck; the values measured on the bridge on the inside do not differ much from those measured on the heliport deck, on the outside;
- the measurements conducted with different broadcasting stations revealed that the electric field intensity values on the heliport deck, in the open, are lower than the values measured on the bridge in confinement. The same was also found during the measurements with the US type NARDA model 8718 series 1507 meter, USA, with probes in the frequency range 300 kHz - 50GHz.

- at low values of the incident electric field strength for dB breaking, and respectively for relative breaking, negative values are achieved. This is due to the radio absorbing material that requires a minimum value of the incident field power in order to be efficient;

- the relative breaking is maintained within values of over 80% going over 95 % in most of the measurements in the band, which highlights the special screening qualities of the protecting material.

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