Measurements of magnetic and electric fieldstrengths in distances of up to 10 m around transmit loop antennas in the frequency range 9 kHz to 30 MHz

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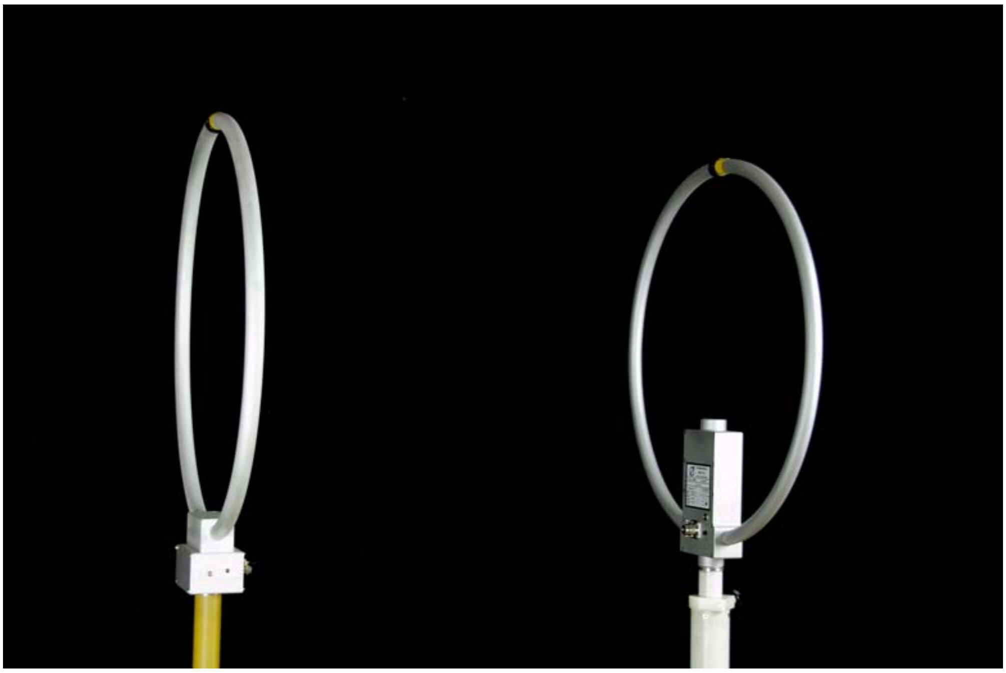

Fig. 1: Transmit loop antenna HFRA 5149 and receive loop antenna FMZB 1513 in parallel plane alignment, distance variable from 0.5 m to 10 m. Both loops have a diameter of 0.5m

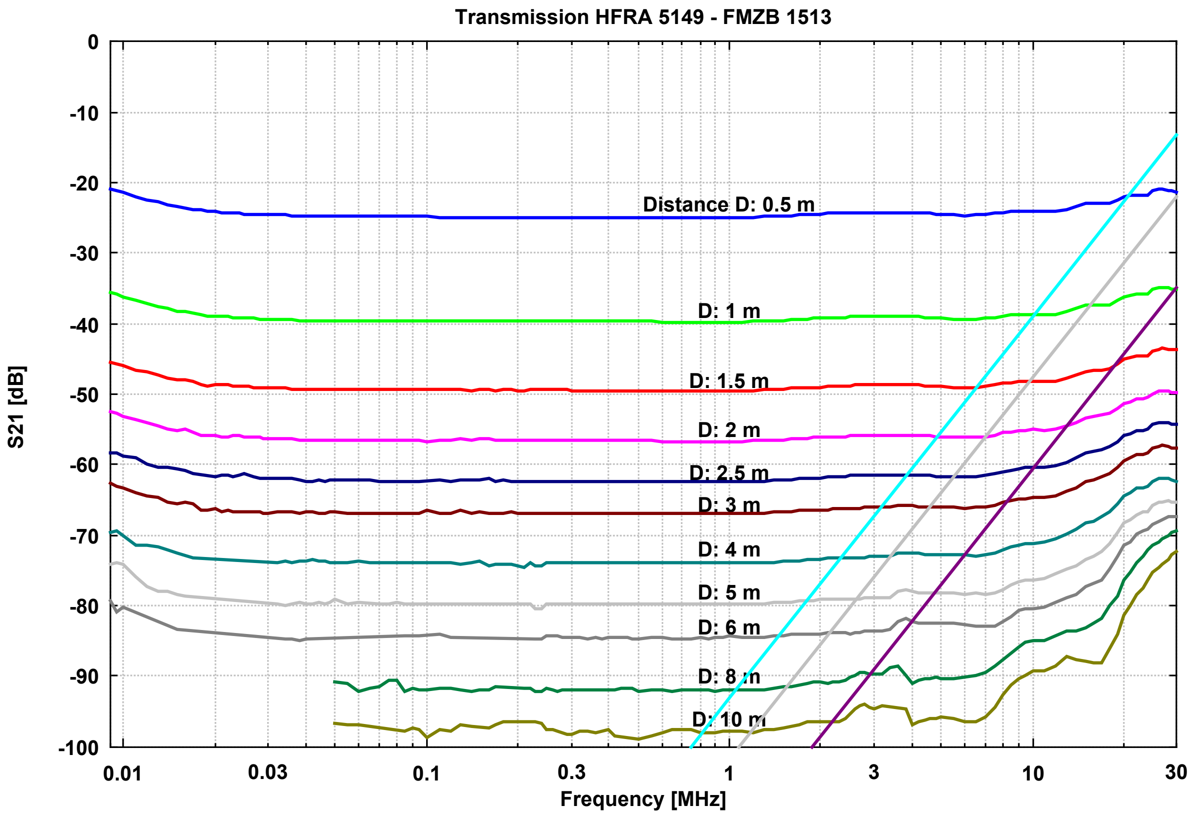

Fig. 2: Measured Transmission at several distances. The theoretical decay for doubling the distance is 18 dB. At very short distances of e.g. 0.5 m the integrating characteristics of the loop can be recognised. Increasing farfield influence can be seen at 30 MHz and larger distances. Doubling the distance from 5 m to 10 m leads to a fieldstrength decay of 6 dB at 30 MHz instead of 18 dB at e.g. 1 MHz.

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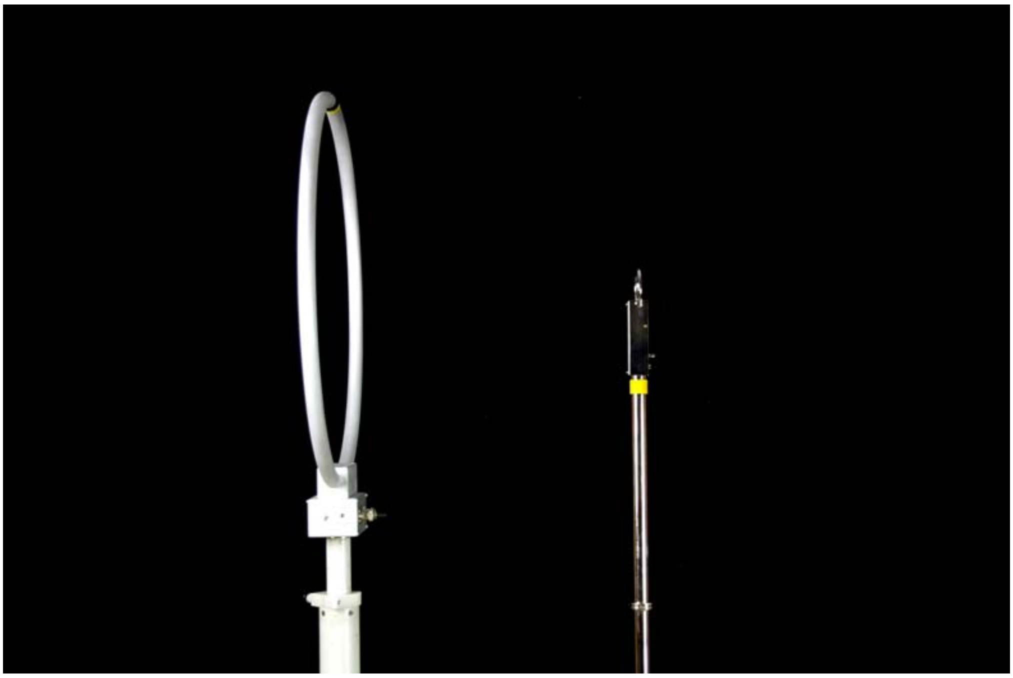

Fig. 3: Axial magnetic fieldstrength component measurement with HFS 1546 in front of a transmit loop antenna HFRA 5149.

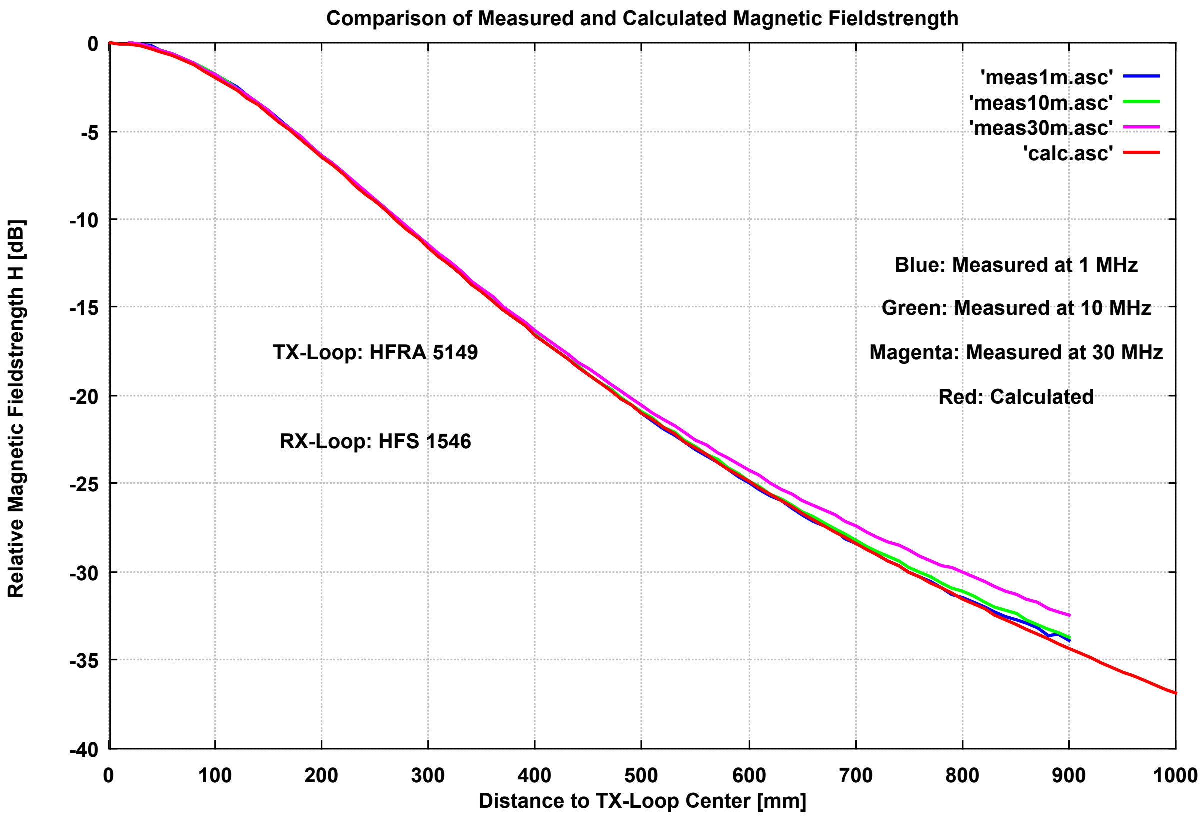

Fig. 4: Comparison of measured data and calculated data based on Biot Savart's equations. Very good agreement for frequencies below 10 MHz. Transition to farfield conditions noticeable at 30 MHz. Data is normalised to the fieldstrength in the center of the loop.

Fig. 5: E-field probe EFS 9218 in front of the transmit loop antenna HFRA 5159. The electric field component is horizontally polarised.

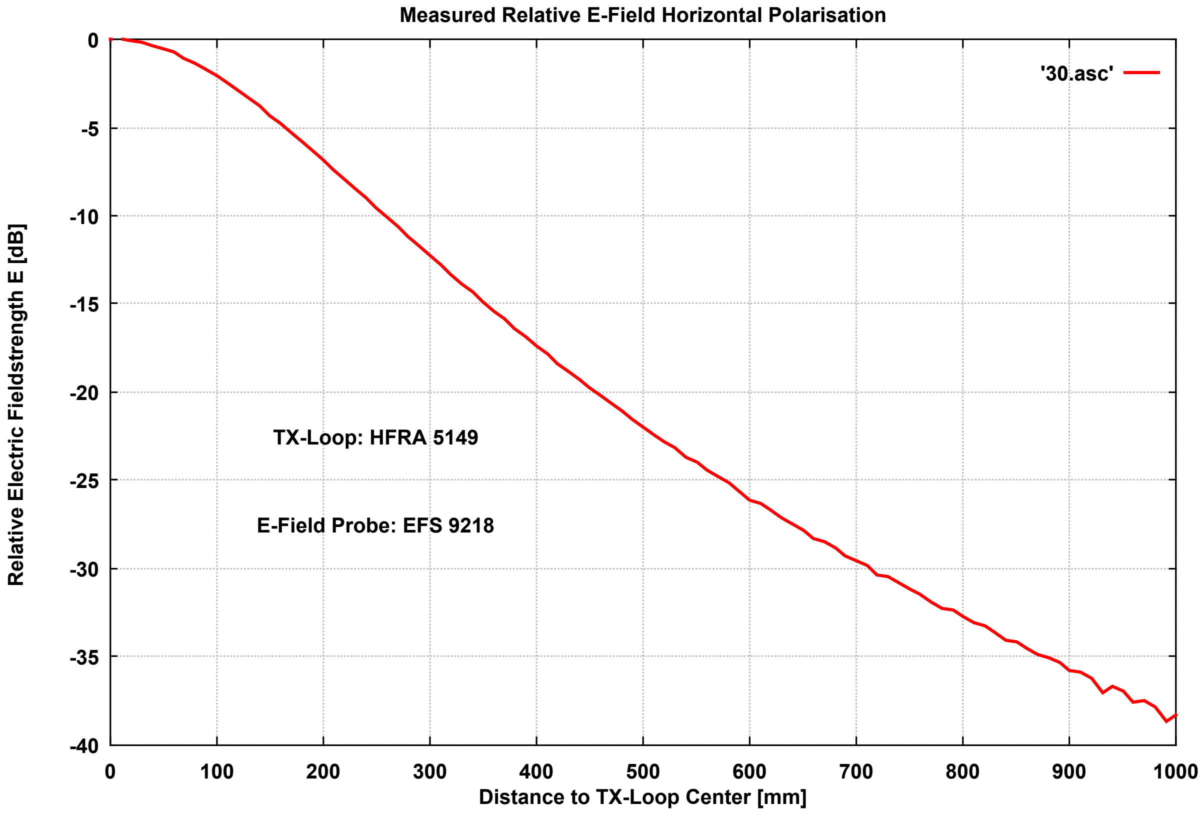

Fig. 6: The relative decay of E-field strength with increasing distance is roughly the same as the decay of the axial H-field strength. Data is normalised to the fieldstrength in the center of the loop.

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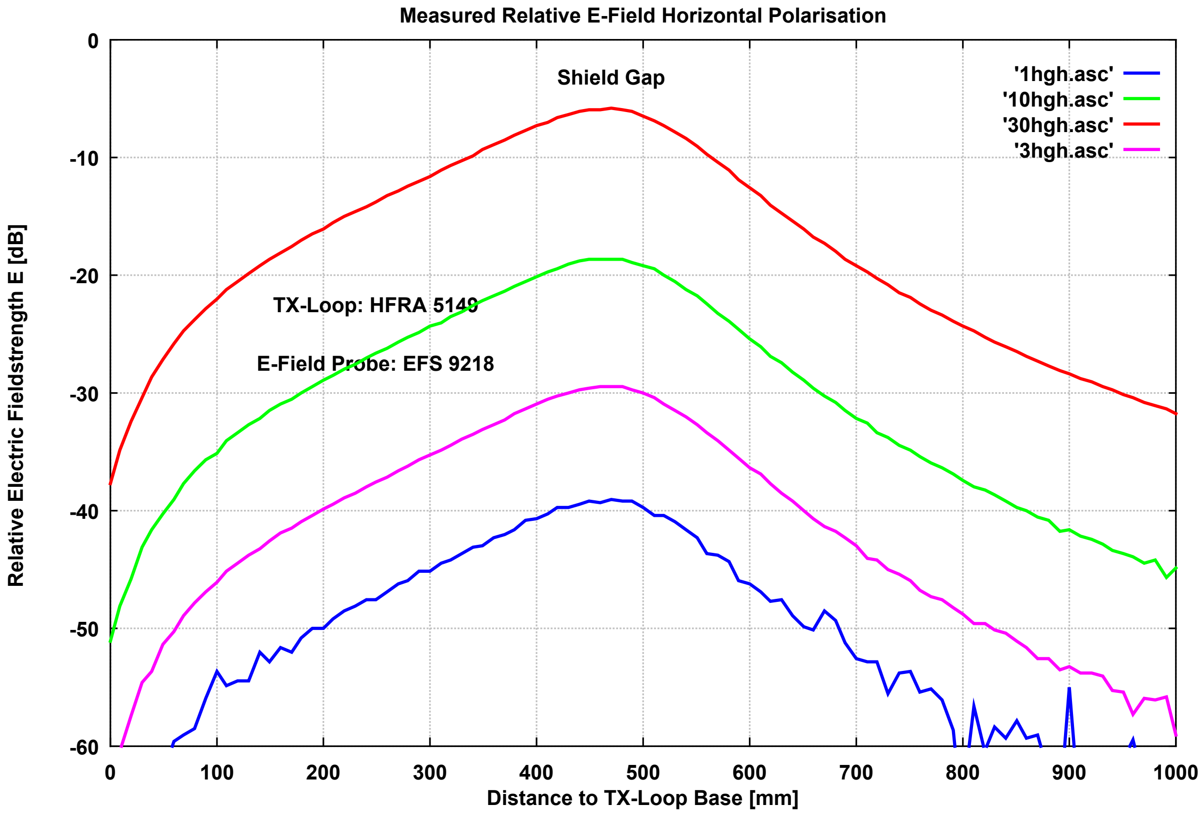

Fig. 7: Measured E-fieldstrength in front of a transmit loop HFRA 5149 at frequencies between 1 and 30 MHz. The small E-field probe EFS 9218 (see Fig. 5) was moved in height. The highest values are obtained directly at the shield gap, which is located at a height of 480 mm. The E-fieldstrength rises with 20 dB per decade of frequency (compare blue (1 MHz) and green curve (10 MHz). The shield of the loop has its self resonance around 100 MHz. At 30 MHz the shield of the transmit loop acts like a dipole with a length of $\lambda/6$.

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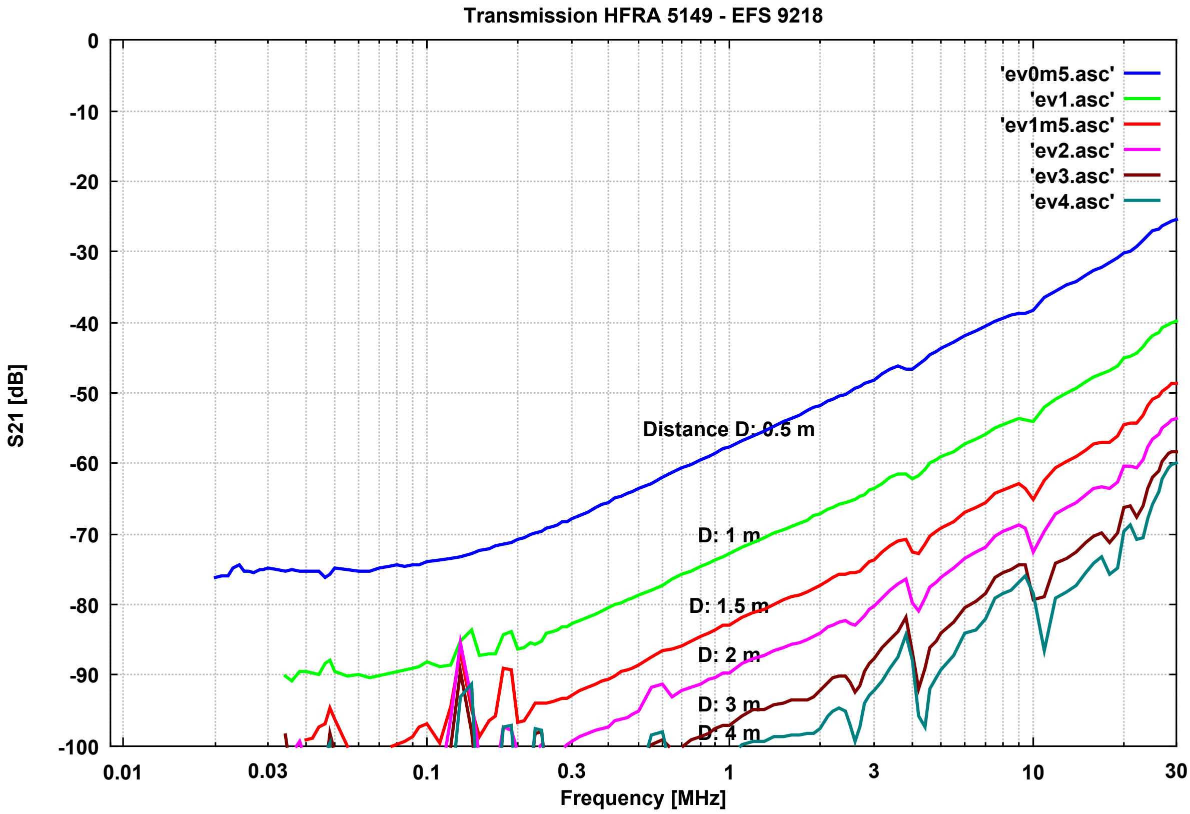

Fig. 8: Measured E-field data according to Fig. 5. Unwanted sheath current influences are especially visible at 10 MHz and large distances.

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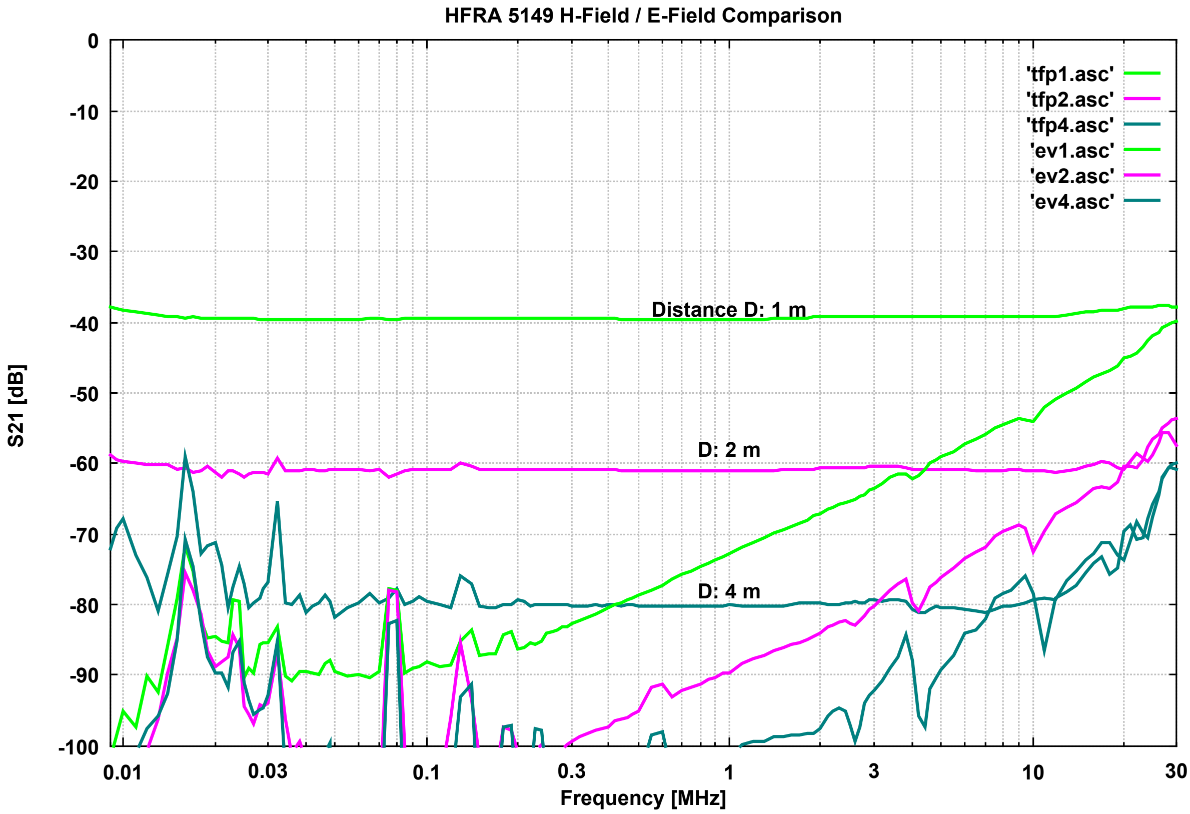

Fig. 9: The intersection of magnetic field and electric field characteristics are also indicating the nearfield to farfield transition in the frequency range of interest. The shorter the distance and the lower the frequency, the better the rejection of E-field component. The exact prediction of fieldstrength requires analysis of all three field components according to Fitzgeralds' model of a magnetic dipole.

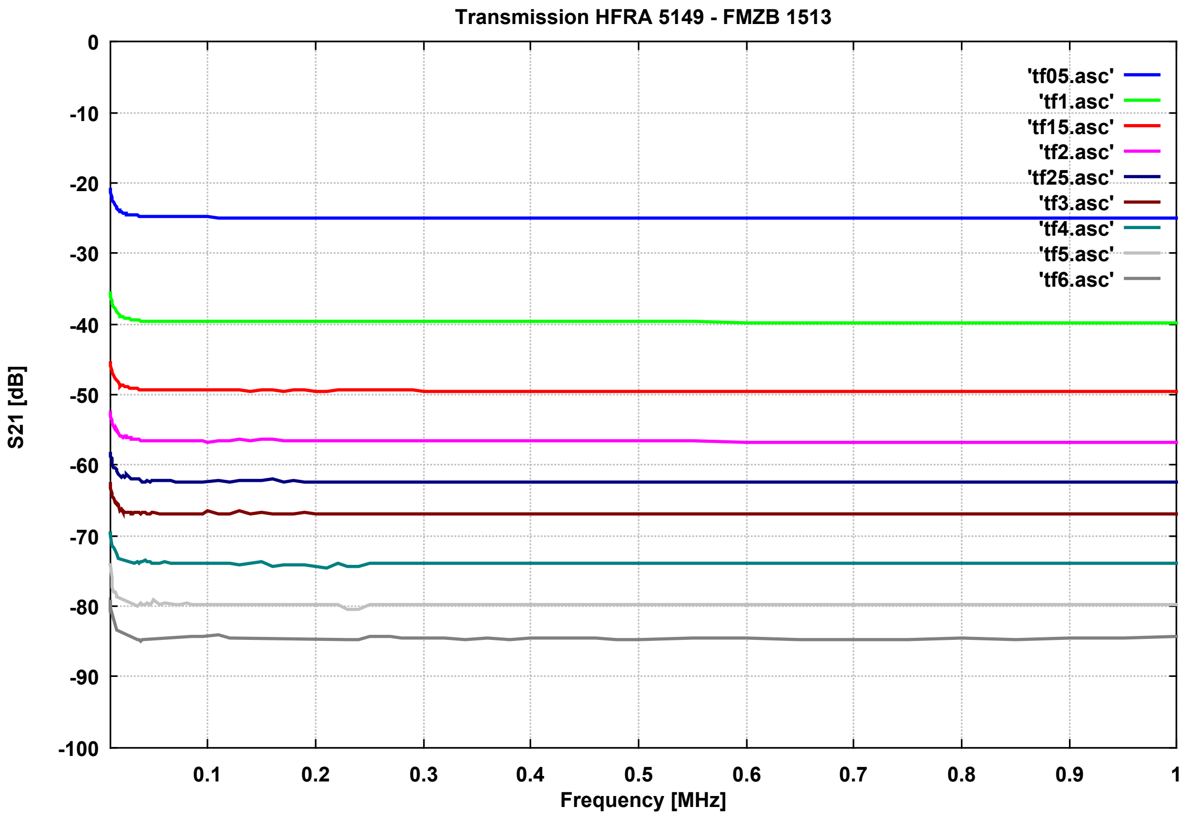

Fig. 10: Expanded low frequency range of Fig. 1 with linear frequency axis

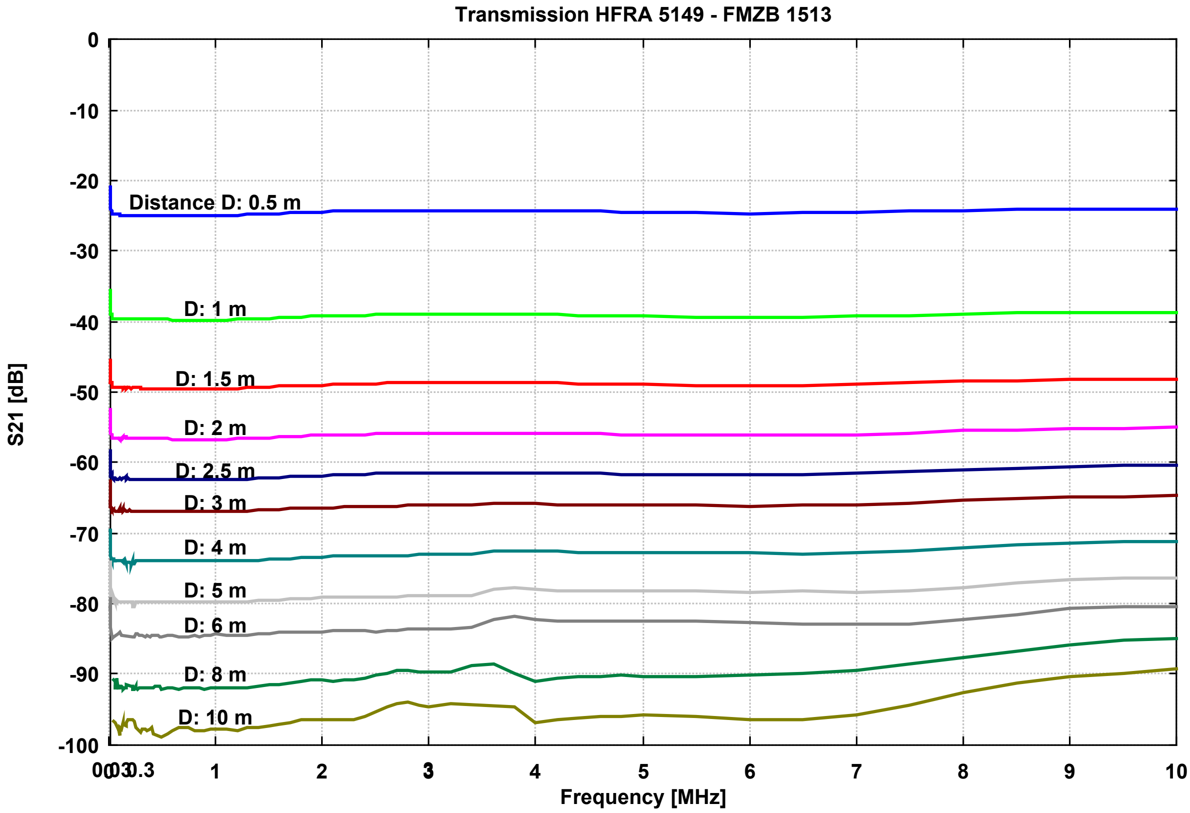

Fig. 11: Expanded medium frequency range of Fig. 1 with linear frequency axis

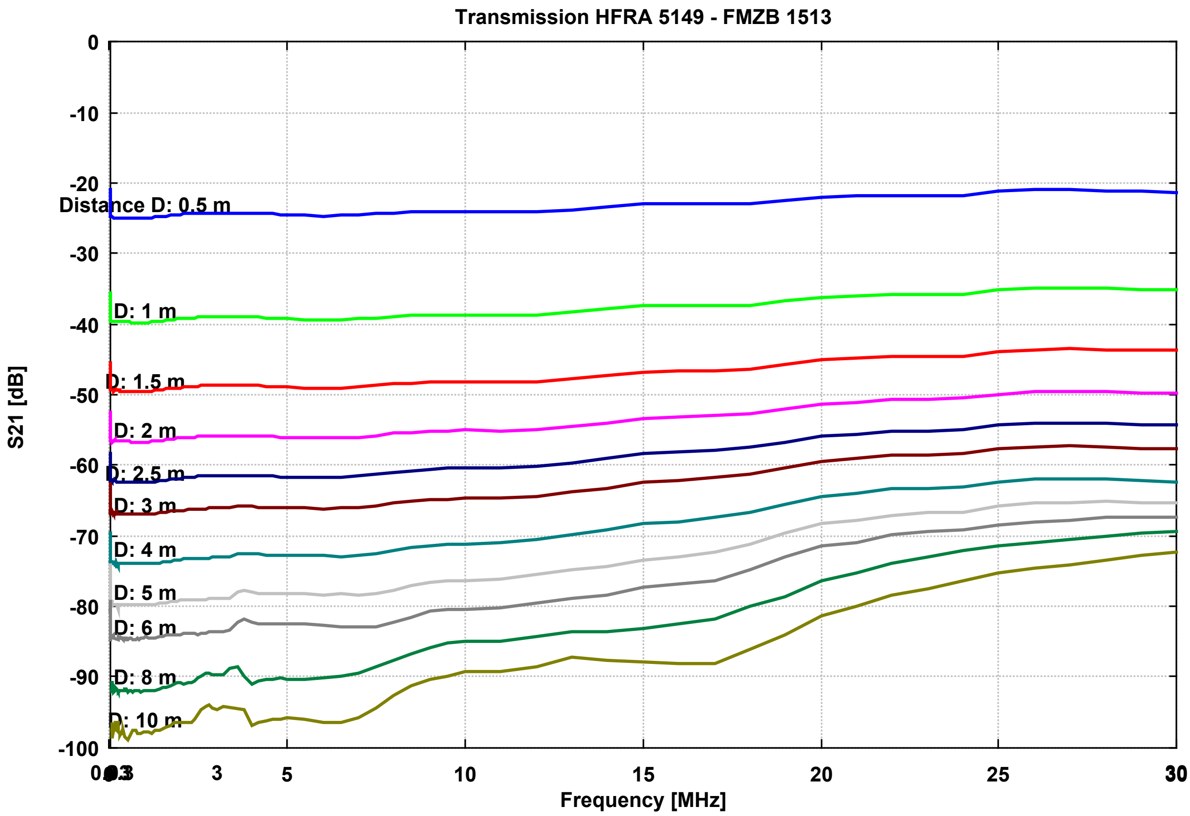

Fig. 12: Data of Fig. 1 with linear frequency axis

Measurements of magnetic and electric fieldstrengths in distances of up to 10 m around transmit loop antennas in the frequency range 9 kHz to 30 MHz

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Frequency	10 kHz	30 kHz	100 kHz	300 kHz	1 MHz	3 MHz	10 MHz	30 MHz
Wavelength λ	30 km	10 km	3 km	1 km	300 m	100 m	30 m	10 m
Circumference of a loop of 0.5 m diameter	λ/20000	λ/7000	λ/2000	λ/700	λ/200	λ/70	λ/20	λ/7
Distance 1 m - 10 m	λ/30000- λ/3000	λ/10000- λ/1000	λ/3000- λ/300	λ/1000- λ/100	λ/300- λ30	λ/100 - λ/10	λ/30 - λ/3	λ/10 - λ
Conditions	Nearfield	Nearfield	Nearfield	Nearfield	Nearfield	Transition	Transition	Transition / Farfield

Some conclusions obtained from the measurements:

- Influence of loop size is visible at short distances (Fig. 2)
- The transition from nearfield to farfield is around 10 MHz (Fig. 2)
- Richtdiagramm Nahfeld / Fernfeld untersuchen, ab ca. 15 MHz kaum Richtwirkung mehr sichtbar
- Bei 15-30 MHz und Abständen von 8-10 m ist die Transmission besser bei parallel in Linie ausgerichteten Rahmen
- Magnetic field decreases with 60 dB/Decade of distance, i.e. 18.06 dB per octave of distance (Fig. 2, 10)
- Fieldstrength decay exponent between 1 (farfield) and 3 (nearfield) (Fig. 2, 11)
- Sheath currents are very strong above 10 MHz, supression required (Fig. 2,8,9)
- The loop shield acts as a short dipole from approx. 20-30 MHz (hand sensitive when touching the shield gap) (Fig. 8,9)
- The nearfield pattern of a 0.5 m loop is accurately 8 shaped up to 15 MHz, above this frequency it will become more oval
- Transmit loop antennas are generating E-fields as well, which are increasing with 20 dB per decade of frequency (Fig. 8, 9)
- The product of frequency and distance or the ratio of wavelength and distance is important for the farfield / nearfield decision (Fig. 2)
- A shielded transmit loop antenna creates a horizontally polarised E-field when the gap of the shield is located on top, the maximum E-field is at the gap (Fig. 5, 7)
- Since a majority of measurements is made under nearfield conditions, there are relevant field components in all directions. The use of a triaxial field probe is recommended to reduce the measurement effort. (Fig. 13, 14)
- The typical measurement uncertainty for the calibration of loop antennas is in the order of 1 dB
- Large level differences of typically 100 dB require good shielding effectiveness of cables and measuring apparatus with high dynamic range (Fig. 2)

Fig. 13: 3-axial loop antenna 9 kHz - 200 MHz FSH3D

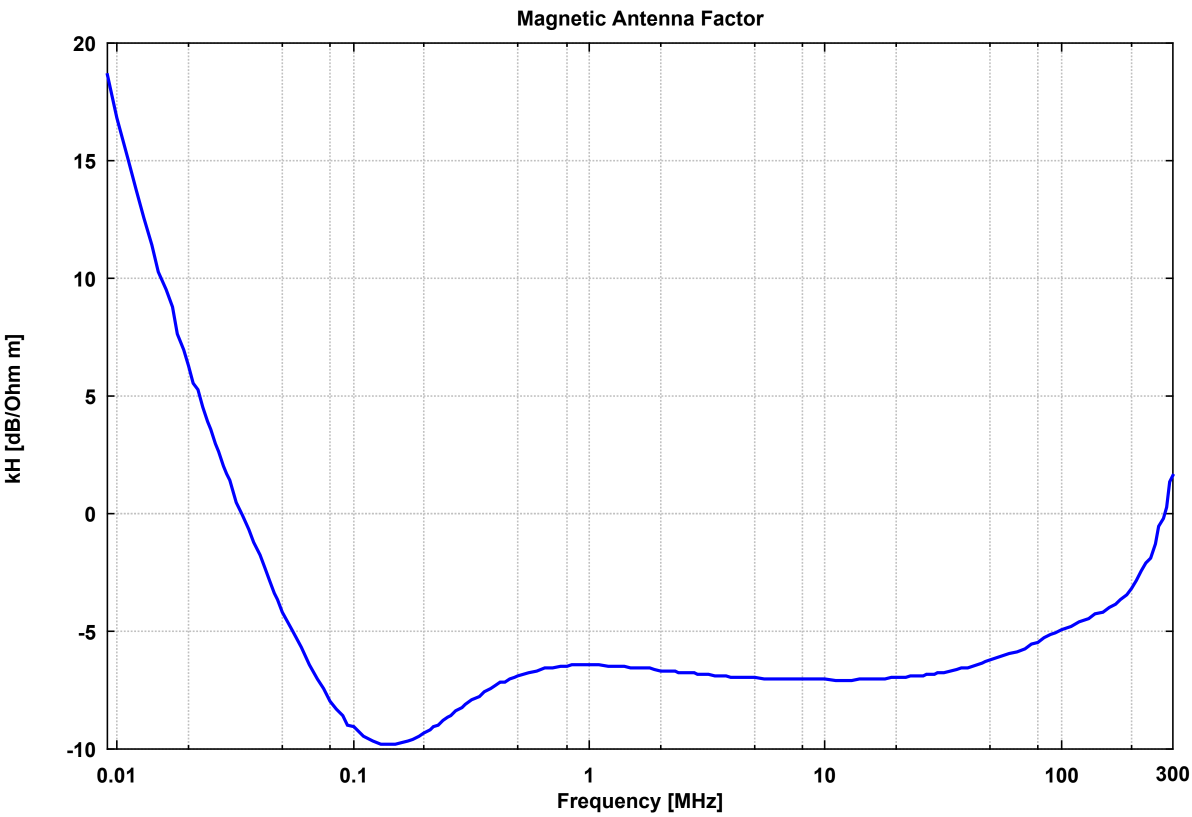

Fig. 14: Magnetic Antenna Factor 3-axial loop antenna FSH3D