# DESIGN AND REALIZATION OF A NEW TYPE ELECTRIC FIELD PROBE (400MHZ-1GHZ)


Ersan BARAN[1,2] Prof.Dr. Osman ÇEREZCİ[1] Fatih ÜSTÜNER[2]
Ali DAĞDEVİREN[2] Bahattin TÜRETKEN[2] Mehmet YAZICI[2]

*[1]SAKARYA UNIVERSITY, Sakarya-TURKEY*
*[2] The Scientific and Technical Research Council of Turkey (TÜBİTAK–UEKAE)*
*P.O. Box.74, 41470 Gebze, Kocaeli, TURKEY*
*e-mail:ersanbar@uekae.tubitak.gov.tr*



**Abstract: In this study, we have designed a protoype electric-field probe. E-field probes consisting of a dipole antenna, RF detector, nonperturbing data transmission line, and readout device can be implemented in a variety of ways. The probe has a single dipole antenna, a logarithmic detector and a fiber optic link for data transmission. The probe has been calibrated according to the procedures declared in IEEE std 1309-1996. Data has been processed and results are presented.**


## I. INTRODUCTION

As known, electric field probes are used widely in quantifying hazardous electromagnetic (EM) fields. As these field probes are evaluated, their dynamic ranges, sensitivity and vulnerability of the transmission lines should be taken into consideration.
Most E-field probes have used diode detectors. Low-end of the dynamic range depends on the diode detectors, since there is no way out to measure the lower fields other than a Schottky diode can sense. 0.3 volt is the minimal point that a Schottky diode detector can work. In this work, a logorithmic detector is used instead of a Schottky diode detector. Logorithmic detector can detect RF signals –70 dBm to 0 dBm in level, that means 70 dB dynamic range for the detector. For the electric field probe, this sensitivity or dynamic range may not be retained because of dipole correction factor. Reception by the dipole antenna is saturated, and limited to some value.
Most electric field probes have transmission lines which is origin of the erronous readings. This is overcome by means of a fiber-optical link. Link is 5 meter long.

## II. BASIC PRINCIPLES OF OPERATION

Most electric field probes have been constructed similar to that shown schematically in Fig. 1. As seen on the figure, probe contains four basic elements: a dipole antenna, a dedector, a nonperturbing transmission line or fiber optical link, and computing device. Between dipole and detector, there is a resistive matching network. The last part of the figure is multimeter and a computer. Some other E-field probes have optional filtering networks, here, detector has a built-in filtering in its operating frequency range.
Continuous-wave incident field with the frequency ω across dipole produces an oscillating votage input to the detector. Since the logarithmic detector has an input power in dBm to ouput DC voltage characteristic, a DC voltage has been developed at the output of the detector.
In the analysis, for simplicity, the incident continuous-wave electric field is assumed to be parallel to the axis of the dipole:

$$\vec{E}_z^{\,i}(r,t) = E_z^{\,i}(\vec{r})\cos[\varpi t + \phi_z(\vec{r})]\hat{z}$$

$$= \mathrm{Re}\left[E_z^{\,i}(\vec{r},\varpi)e^{j\varpi t}\right]\hat{z} \qquad (1)$$

where Re indicates reel part.

The incident electric field generally is not uniform along the axis of the dipole antenna (z axis). Spatial resolution of the field is provided by making the antenna physically short and electrically short , $\beta_0 = 2\pi h/\lambda_0 \langle\langle 1$ , where h is the half-lenght of the dipole and $\lambda_0$ is the wavelenght in free space. Spatial resolution is determined by the variation of the incident field over the lenght of the dipole. For high resolution, the lenght of the dipole should be small compared to the distance over which the gradient of the electric field is significant. The voltage across the terminals of the electrically short dipole when the terminals are open circuited is about proportional to the incident electric field at the center of the dipole:

$$V_{oc}(\varpi) \approx hE_z^{\,i}(0,\varpi) \qquad (2)$$

and the impedance of the driven dipole is about capacitive:

$$Z_A(\omega) \approx -j/\omega C_A = -j\xi_0[\ln(h/a_A)-1]/\pi\beta_0 h \qquad (3)$$

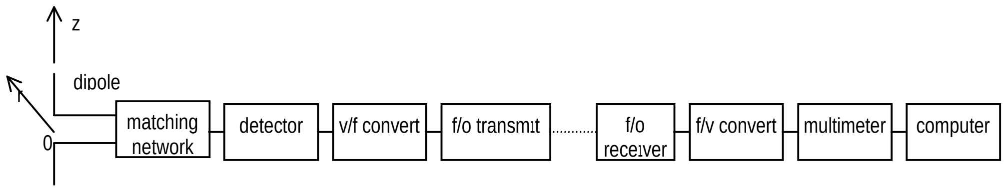


**Fig. 1.** Schematic of E-field probe.

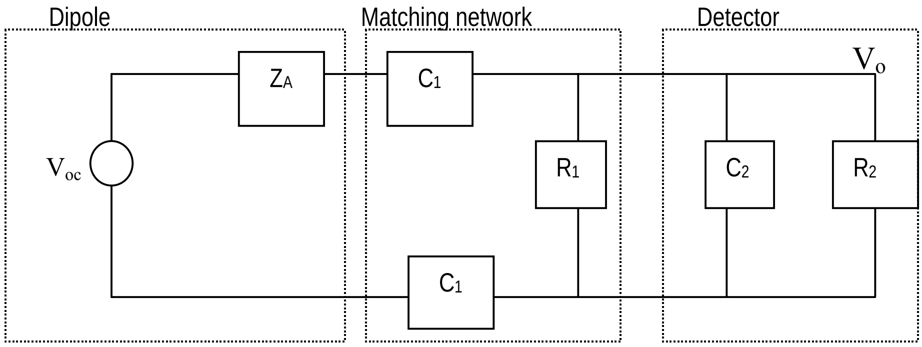


**Fig. 2.** Equivalent circuit for the receiving dipole.

where $a_A$ is the radius of the driven dipole conductor and $\xi_0$ is the impedance of free space. These two elements, the open circuit voltage and the antenna impedance, form the Thevenin equivalent circuit for the receiving dipole shown on the left part of Fig. 2.

**Detector**

The detector used in the probe is a complete multistage demodulating logarithmic amplifier, capable of accurately converting an RF signal at its input to an equivalent decibel-scaled value at its dc output. Detector maintains a high degree of log conformance for signal frequencies from 0.1 GHz to 2.5 GHz. The nominal input dynamic range is –65 dBm to 0 dBm. Detector requires 2.7 V-5.5 V supply voltage and suitable input and supply decoupling. Detector output runs from about 0.45 V dc at –73 dBm input to 1.75 V dc at 0 dBm input. The detector gives lineer response to power between about –70 and 0 dBm. Detector input impedance at 100 MHz is $R_2$ =900 Ω in parallel with a capacitance of $C_2$ =1.1 pF. Detector input impedance is represented in the right part of Fig. 2. In the middle part of Fig. 2, a simple 50 Ω matching network is used. A termination resistance of $R_1$=53.6 Ω combines with the internal input impedance of the detector ($R_2$ =900 Ω) to give an overall resistive input impedance of about 50 Ω. The termination resistor should preferably be placed directly across the input pins where it serves to lower the possible deleterious efffects of dc offset voltages on the low end of the dynamic range. In matching network, two 680 pF input coupling capacitors set the high pass corner frequency of the detector at 9.4 MHz. At the beginnig, this resistive matching has been done since ease of use. Detector theoretical characteristic is given in Fig. 3.

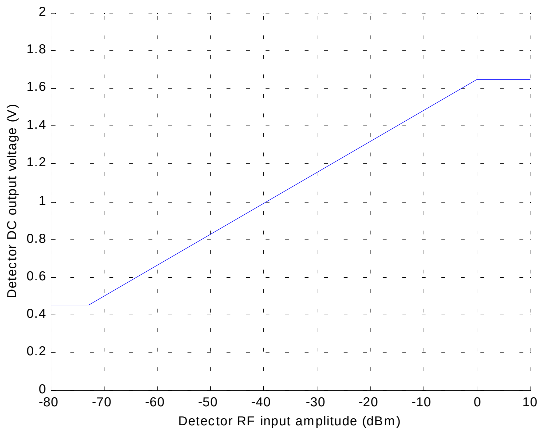


**Fig. 3.** Detector theoretical characteristic

## Probe Response

The rough response for the probe , the voltage Vo on Fig. 2, can be determined from Fig. 2. In Fig. 2, $R=R_1//R_2$ and $C_2$ are combined as $Z_{int}$. If the current I on the left mesh of Fig. 2 is found by,

$$-V_{oc} + I*(X_{CA} + X_{C1} + Z_{\text{int}} + X_{C1}) = 0 \qquad (4)$$

and

$$V_o = I*Z_{\text{int}} = V_{oc} * \frac{Z_{\text{int}}}{X_{CA} + 2X_C + Z_{\text{int}}} \qquad (5)$$

and the overall transfer function,

$$\frac{V_o}{V_{oc}} = \frac{\omega R C_1 C_A}{\omega R(C_1C_2 + 2C_2C_A + C_1C_A) - j(C_1 + 2C_A)} \qquad (6)$$

where $Z\,\text{int} = R // X_{C2}$,

$$X_{C1} = \frac{1}{j\omega C_1}, \quad X_{C2} = \frac{1}{j\omega C_2}, \quad X_{CA} = \frac{1}{j\omega C_A}.$$

The overall theoretical transfer function with respect to frequency is plotted on Fig. 4,

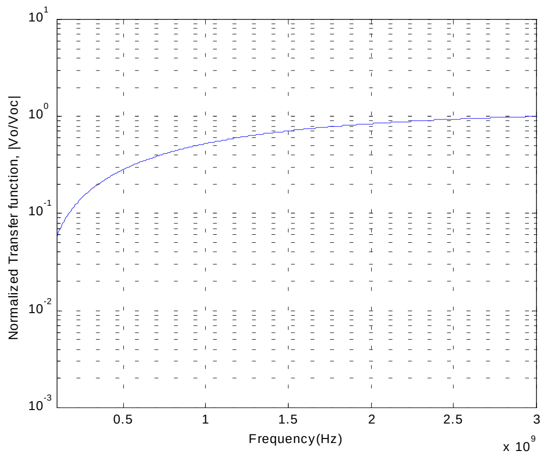


**Fig. 4.** Normalized transfer function of the probe versus frequency

## Calibration

In calibration of the E-field probe, IEEE 1309-1996 procedures have been followed. This standard provides alternative calibration methods that are appropriate to various frequency ranges and various user requirements. These methods are applicable to any (active, passive, photonic, etc.) field sensor or field probe. Methods are provided for frequency domain and time domain calibration. In this application, calibration has performed in GTEM cell, in frequency domain, and transfer standard probe has been used. At the beginnig, although frequency range has been selected as 100 MHz-1000 MHz, frequency flatness has been obtained in 400 MHz-1000 MHz. Calibration has been performed automatically by means of software routines. Software has been prepared by using a C-based programming environment. User interface belonging to the application is shown on Fig. 5.

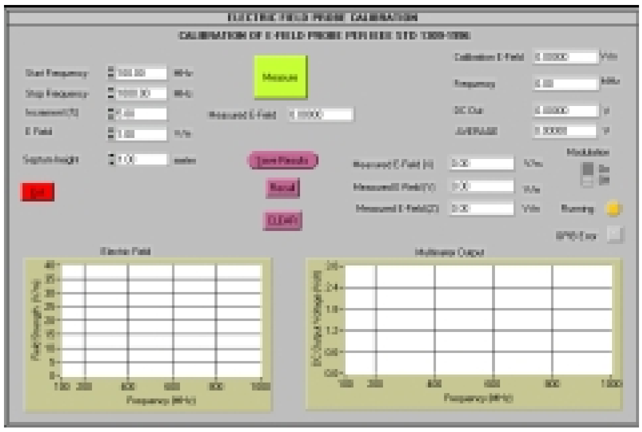

**Fig. 5.** Calibration software user interface

1, 10, 20, 30, 40, and 50 V/m are used as calibration amplitude levels. These levels are applied in the calibration frequency range. 20 and 50 V/m results are shown on Fig. 6.

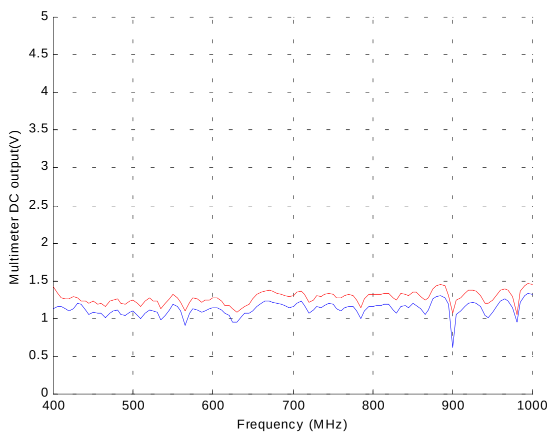


**Fig. 6.** Multimeter DC Outputs for 50 and 20 V/m

As shown on the Fig. 6, frequency response to every calibration amplitude level has same envelope. In fact, this values versus frequency are desired to be constant values. Since that condition can not be reached, average values over frequency are used in determining the frequency independent correction data. As needed correction data should depend on the amplitude levels only. E-field level-DCoutput characteristic is expected to resemble to the detector theoretical characteristic on Fig. 3. E-field level-DC output characteristic is shown on Fig. 7.

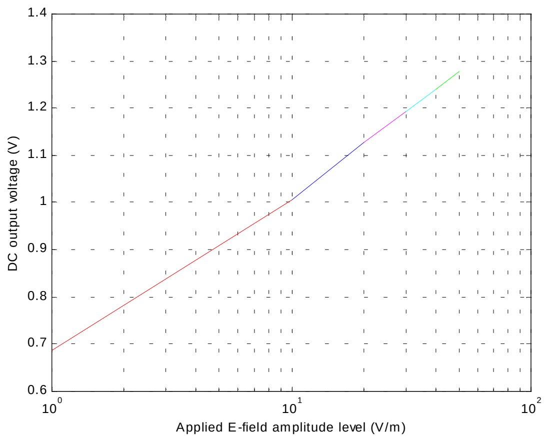


**Fig. 7.** E-field amplitude level-DC output characteristic

As seen on Fig. 3 and Fig. 7 and Fig. 8, plots have resembling inclines, only horizontal axises are E-field and power levels. E-field and power levels are convertable to each other. More reliable plot, $S= E^2/Z_0$, is power density is shown on Fig. 8 where S is power density, E is applied E-field, Zo is free space impedance.

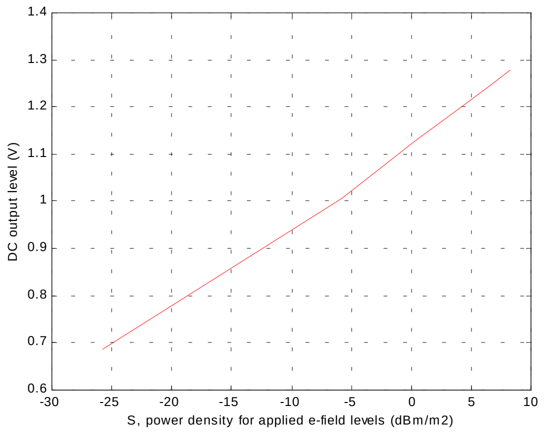


**Fig. 8.** S, power density versus DC output level plot.

Correction data is said to be frequency independent. If the frequency content of the E-field measured is known then calibration factor added to the correction factor can be provided for more accurate measurements. As a result of calibration, ±4 -±5 dB voltage sensitivity has been revealed after processing of the data.

**Telemetry System**

E-field probe response is affected mostly by transmission lines. Secondary or scattered fields are main source of measurement errors. For this reason, until a few decade ago, resistive transmission lines were used to convey data. These transmission lines behaves like a low pass filter. Those provide RF protection at a level. By means of optical linkages, this problem has been solved completely since data in light can not be distorted in RF environment.

## III. CONCLUSION

In this work, an electric field probe is implemented. The matter subjected to this work is the dipole antenna. Antenna signals that is produced by the electric field, are leveled by the detector which is in the unit used with the dipole antenna, transmitter part. Detector used is different than other diode detectors, since it is logarithmic and it has been experienced as a probe detector.

Different field level signals produced by electric field probe are carried to the receiver part by the fiber-optical cables which are part of the telemetry system, not by the hard-wire cables. Telemetry system allows the measurement signals to carry without usage of the hard-wire cables such as carbon-film, metalik, or teflon cables. Telemetry system has been used successfully.

For the calibration of the electric field probe, as the laboratory opportunities are enough IEEE std 1309-1996 document porcedures are followed. For the calibration of the electric field probe, a calibration software is prepared in which this document procedures are based on.

Fig. 6 shows E-field probe response curves at 20 and 50 V/m levels. These curves are, not absolutely flat curves, caused by:

- Field generation facility, GTEM,

  At high frequencies in GTEM, the measured field may vary up to about ±4 dB
- Transfer Standart,
- Equipment for generating field,
- Dipole matching and E-field spatial resolution.

A prototype E-field probe in this work is needed to improve:

- Shielding integrity,
- Extending frequency range,
- Field generation by Standard Field Method,

will improve the performance of the E-field probe.
An E-field probe has been developed and used over RF spectrum. In complex near zone fields, electric field value at a point can be expected to give by those probes whose maximum dimension is a small fraction of a wavelength. Broadband E-field probes with 1-2 dB uncertainty are being developed in complex near field environments.

## REFERENCES


[1]. HOWARD I. BASSEN, GLENN S. SMITH, Electric Field Probes-a Review, IEEE Transactions On Antennas and Propagation, Vol. AP-31, No.5, September 1983.

[2]. IEEE Std 1309-1996 “IEEE Standard For Calibration Of Electromagnetic Field Sensors And Probes Excluding Antennas, From 9 kHz to 40 GHz.”, 1996.

[3]. A New Near-Zone Electric Field–Strength Meter, NBS TECHNICAL NOTE 345 November 15, 1966.

[5]. National Instruments, LabWindows/CVI C For Virtual Instrumentation documentation.

[6]. E.B. LARSEN, F.X. RIES, Design And Calibration Of The NBS Isotropic Field Monitor (EFM-5), 0.2 To 1000 MHz.

[7]. Analog Devices , Logarithmic Detector/Controller, AD8313.

[8]. Ersan BARAN, Electric Field Probe, MSc Thesis, Sakarya University, 2001.