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EFFECT OF ELECTROMAGNETIC WAVES ON THE ELECTRICAL AND RECOMBINATION PARAMETERS OF A HORIZONTAL-JUNCTION SILICON SOLAR CELL: A COUPLED STUDY OF THE ELECTRIC AND MAGNETIC FIELDS

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ABSTRACT

This work theoretically investigates the effect of an electromagnetic wave — modelled through the simultaneous action of an electric field E (drift) and a magnetic field B (reduction of the diffusion coefficient) — on the electrical and recombination parameters of a horizontal-junction silicon solar cell, in the frequency dynamic regime. Solving the coupled continuity equation yields, from a single set of curves, the short-circuit photocurrent density (Jsc), the open-circuit voltage (Voc), the maximum electrical power and the critical recombination velocities Sfco and Sfcc as functions of E and B. The results, presented as three-dimensional surfaces, show that the electromagnetic wave markedly degrades performance: between the field-free case and (E = 5 V/cm, B = 0.1 T), Jsc drops from 31.3 to 22.1 mA/cm^2 (≈ −29%) and the maximum power from 16.8 to 12.8 mW/cm^2 (≈ −24%), while the open-circuit voltage rises slightly (0.643 → 0.686 V) and the critical velocities Sfco and Sfcc decrease by a factor of about six to eight. The effect of the two fields is cumulative, highlighting the combined impact of the E and B components of an electromagnetic wave on photovoltaic conversion.

Keywords: Silicon solar cell; Electromagnetic wave; Electric field; Magnetic field; Frequency dynamic regime; Critical recombination velocities.

1 INTRODUCTION

The growing cohabitation between solar panels and sources of electromagnetic waves — telecommunication antennas, radio transmitters, 5G networks — raises the question of the effect of these waves on solar-cell performance. An electromagnetic wave inherently combines an electric field and a magnetic field oscillating in phase at a given frequency. In a silicon solar cell, each of these fields modifies minority-carrier transport: the magnetic field reduces the diffusion coefficient [3, 4], while the electric field introduces a drift component [5].

Recent literature has treated separately the effect of the magnetic field [3, 4, 7] and that of the electric field [5], as well as the overall effect of an electromagnetic field in the static regime [6]. Frequency-domain impedance and recombination-velocity studies of silicon solar cells have also been reported [8, 9]. However, the simultaneous action of both fields, coupled with a frequency-modulation study, has not been addressed in this form. This work proposes a unified analysis: from a continuity equation jointly incorporating drift (E field), reduced diffusion (B field) and the dynamic term (frequency ω), we determine the coupled evolution of the electrical and recombination parameters and map their dependence on the (E, B) plane. This approach provides a direct reading of the effect of an electromagnetic wave on photovoltaic conversion.

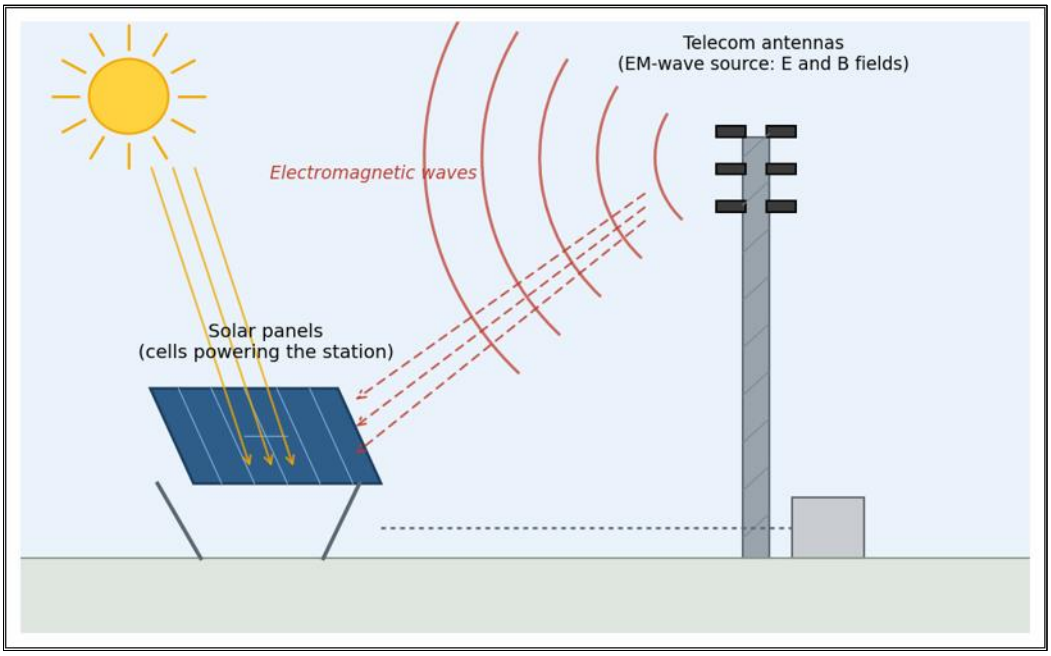

Figure 1: Telecommunication relay station powered by solar panels: the solar cells are directly exposed to the electromagnetic waves (E and B fields) emitted by the station's antennas.

Figure 1 illustrates the problem motivating this work. A growing number of telecommunication relay stations, often located in remote or off-grid areas, are powered by photovoltaic solar panels. Yet these same installations host the transmitting antennas, which continuously radiate electromagnetic waves. The solar cells are thus placed in the near field of intense EM sources, simultaneously experiencing the electric and the magnetic components of the wave at the emission frequency. The originality of this work is to quantify, within a unified theoretical framework, the effect of this exposure on the cell parameters — an E–B–frequency coupling that remains little studied but whose practical importance grows with network densification (radio, television, mobile telephony, 5G).

The nature of the fields considered should be specified. Actual exposure levels in the vicinity of a relay station are modest — an electric field of the order of 0.1 to a few tens of V/m and a magnetic field of the order of μT in the far field ($B \approx E/c$) — and the corresponding effect, taken alone, would be very small. The values of E and B used here are therefore model parameters, swept over an extended range consistent with the applied fields used in laboratory studies (cf. refs [3, 4]), in order to clearly reveal the mechanism and the sign of the combined action of the two fields. The results should be read as trends — the evolution and sign of the variations — rather than as absolute values corresponding to a given emission site.

2 THEORY

We consider a horizontal-junction n^+-p-p^+ silicon solar cell of base width H, illuminated on the front face under frequency-modulated monochromatic light. The cell is subjected simultaneously to an electric field E and a magnetic field B — the two components of an incident electromagnetic wave. The magnetic field reduces the minority-carrier diffusion coefficient (magnetoresistance), while the electric field introduces a drift term in the transport.

The continuity equation governing the minority-carrier density δ(x) in the base, in the frequency dynamic regime of angular frequency ω, reads:

$$D(B)\cdot\partial^2\delta/\partial x^2 - \mu E\cdot\partial\delta/\partial x - (1/\tau + j\omega)\cdot\delta = -G(x) \quad (1)$$

where the magnetic field reduces the diffusion coefficient according to:

$D(B) = D_0 / [1 + (\mu B)^2]$ (2)

μE is the drift velocity induced by the electric field, τ the carrier lifetime, and $G(x)$ the generation rate (Furlan–Amon model [2], mobility μ following the Arora model [1]):

$G(x) = \Sigma_i a_i \cdot \exp(-b_i \cdot x)$ (3)

The general solution, combining drift (E field) and field-reduced diffusion (B field) in the dynamic regime, reads:

$\delta(x) = e^{\beta x} \cdot [A \cdot \cosh(\gamma x) + B \cdot \sinh(\gamma x)] + \Sigma_i C_i \cdot e^{-b_i x}$ (4)

with the drift coefficient β and the complex wavenumber $\gamma(\omega)$:

$\beta = \mu E/[2D(B)]$, $\gamma(\omega) = \sqrt{[(\mu E)^2 + 4 \cdot D(B) \cdot (1/\tau + j\omega)]} / [2D(B)]$ (5)

The constants A and B are set by the boundary conditions: recombination at the junction (velocity Sf) and at the back surface (velocity Sb):

$D(B) \cdot \partial\delta/\partial x|_0 = Sf \cdot \delta(0)$; $D(B) \cdot \partial\delta/\partial x|_H = -Sb \cdot \delta(H)$ (6)

The photocurrent density and the photovoltage then follow from $\delta(0)$:

$Jph = q \cdot Sf \cdot \delta(0)$ (7)

$Vph = VT \cdot \ln[1 + (Nb/ni^2) \cdot |\delta(0)|]$ (8)

The complex nature of $\gamma(\omega)$ gives $\delta(0)$ — and hence all parameters — a frequency dependence that is central to the modulation study. The case E = B = 0 recovers the reference cell; the electromagnetic-wave effect is read in the joint evolution of the parameters with E and B.

3 RESULTS AND DISCUSSION

Figure 2 shows the short-circuit photocurrent density Jsc as a function of the fields E and B. Jsc decreases monotonically with each field: the magnetic field reduces the effective carrier mobility and hence their flux towards the junction, while the electric field deflects the carriers by drift. The effect is cumulative, Jsc falling from 31.3 mA/cm^2 (E = B = 0) to 22.1 mA/cm^2 at (E = 5 V/cm, B = 0.1 T).

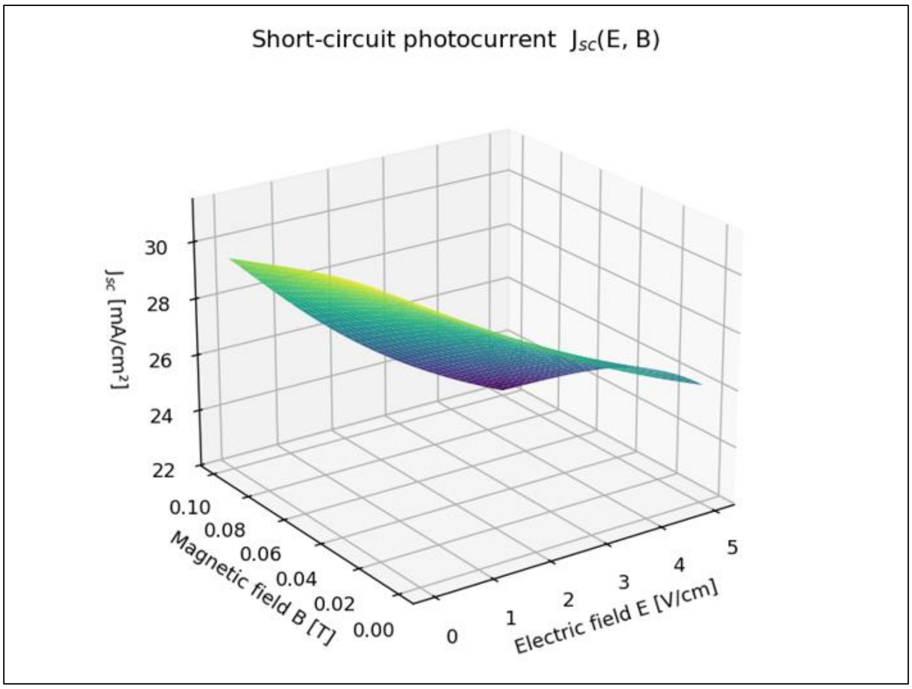

Figure 2: Short-circuit photocurrent density Jsc as a function of the electric field E and the magnetic field B.

Figure 3 shows the open-circuit voltage Voc. Contrary to the photocurrent, Voc increases slightly with both fields (0.643 → 0.686 V): the reduced transport favours carrier accumulation at the junction, which raises the resulting voltage in agreement with equation (8).

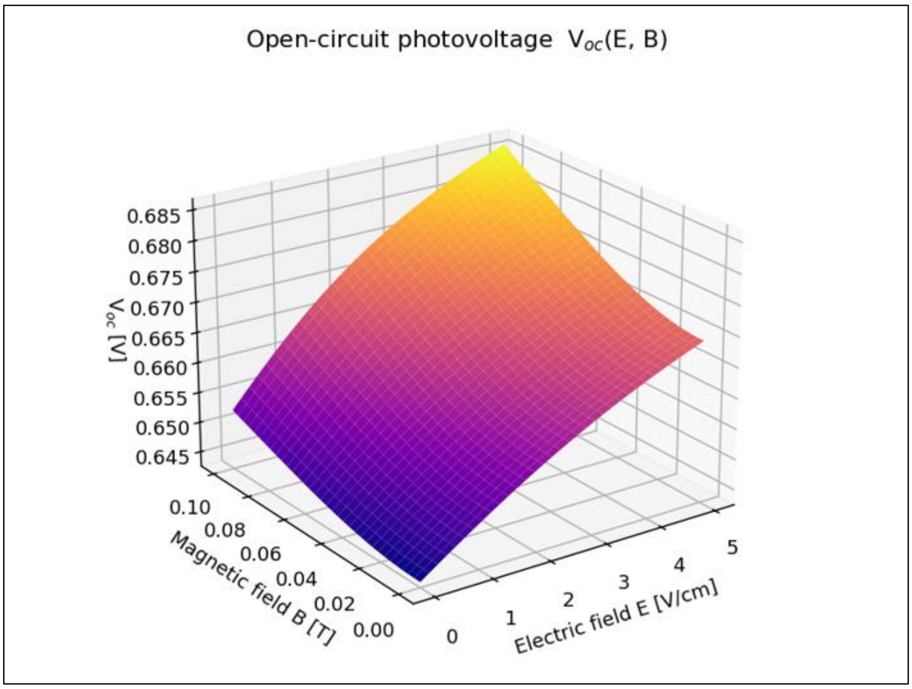

Figure 3: Open-circuit voltage Voc as a function of E and B.

Figure 4 illustrates the maximum electrical power Pmax. Resulting from the product of a decreasing photocurrent and a slightly increasing voltage, Pmax decreases overall with field intensity, from 16.8 to 12.8 mW/cm^2 (≈ −24%): the electromagnetic wave markedly degrades the delivered power.

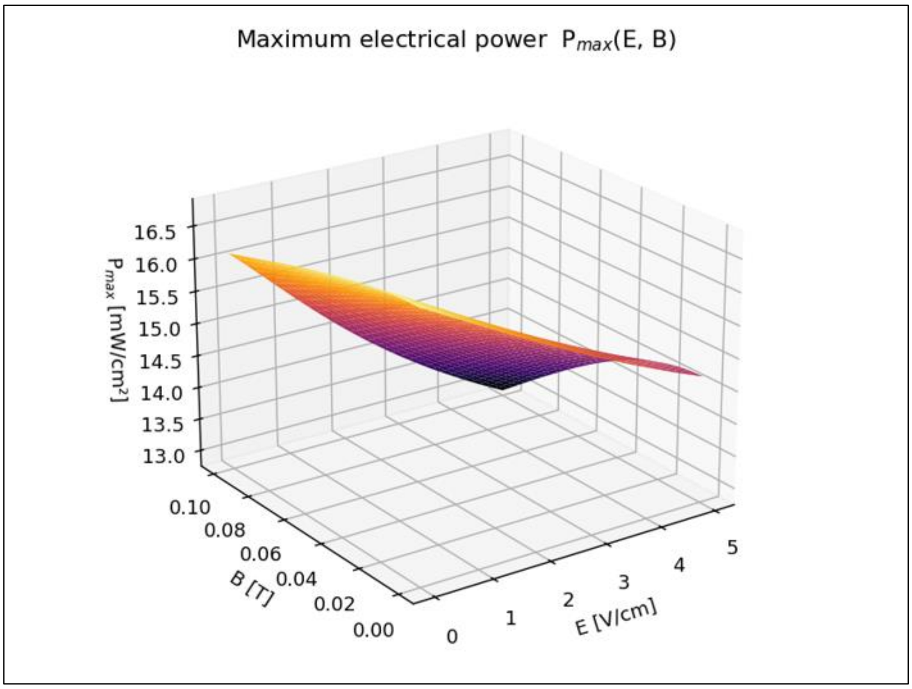

Figure 4: Maximum electrical power Pmax as a function of E and B.

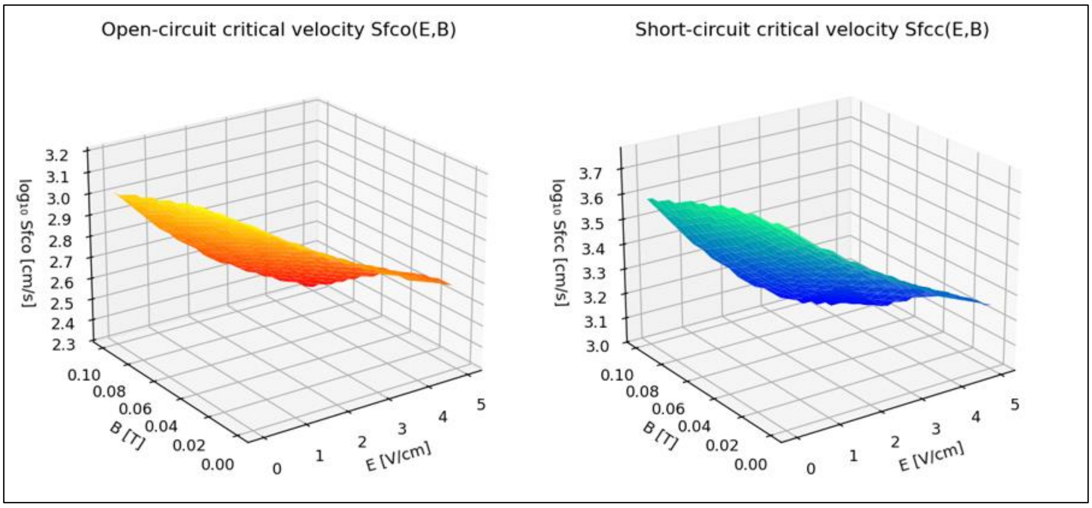

Figure 5: Critical recombination velocities Sfco (left) and Sfcc (right) as functions of E and B (log scale).

Table 1 gathers the numerical values for five representative (E, B) combinations.

Table 1: Electrical and recombination parameters as functions of the fields E and B.

E (V/cm)	B (T)	Jsc (mA/cm^2)	Voc (V)	Pmax (mW/cm^2)	Sfco (cm/s)	Sfcc (cm/s)
0	0	31.30	0.6434	16.83	1.57×10^3	5.85×10^3
0	0.1	29.50	0.6524	16.12	1.04×10^3	3.86×10^3
2.5	0	28.38	0.6584	15.67	7.85×10^2	2.93×10^3
2.5	0.1	24.99	0.6741	14.18	3.66×10^2	1.37×10^3
5	0.1	22.15	0.6859	12.83	2.03×10^2	1.04×10^3

Figure 5 shows the critical recombination velocities Sfco (open-circuit limit) and Sfcc (short-circuit threshold), obtained by the inflection-point method. Both velocities decrease strongly with the fields: Sfco falls from ≈ 1.57×10^3 to ≈ 2.0×10^2

cm/s and Sfcc from ≈ 5.85×10^3 to ≈ 1.0×10^3 cm/s between the field-free case and (E = 5 V/cm, B = 0.1 T). The electromagnetic wave therefore narrows the useful operating range of the cell.

4 CONCLUSION

This work has established, within a unified framework, the effect of an electromagnetic wave — simultaneous electric and magnetic fields — on the electrical and recombination parameters of a horizontal-junction silicon solar cell in the frequency dynamic regime. The results show that the wave degrades conversion: the photocurrent, the maximum power and the critical velocities decrease with field intensity, while the open-circuit voltage increases slightly. The effect of the two components is cumulative, the strongest degradation occurring when E and B act jointly. These results provide a quantitative framework for assessing the impact of electromagnetic waves — notably those emitted by telecommunication antennas — on photovoltaic installations, and pave the way for a complementary study of the frequency response by impedance spectroscopy.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The author declares no competing interests.

Data availability

The data and the numerical worksheets used to generate the figures are available from the author upon reasonable request.

Author contributions

M. S. Diouf designed the study, developed the model, performed the calculations and prepared the figures. A. Thiam and I. Diatta contributed to the analysis and interpretation of the results and to the revision of the manuscript. All authors read and approved the final version.

REFERENCES

[1] Arora, N.D., Hauser, J.R., Roulston, D.J. (1982). Electron and Hole Mobilities in Silicon as a Function of Concentration and Temperature. IEEE Transactions on Electron Devices, 29(2), 292–295. https://doi.org/10.1109/T-ED.1982.20698

[2] Furlan, J., Amon, S. (1985). Approximation of the Carrier Generation Rate in Illuminated Silicon. Solid-State Electronics, 28(12), 1241–1243. https://doi.org/10.1016/0038-1101(85)90048-6

[3] Diao, A., Thiam, N., Zoungrana, M., Sahin, G., Ndiaye, M., Sissoko, G. (2014). Diffusion Coefficient in Silicon Solar Cell with Applied Magnetic Field and under Frequency: Electric Equivalent Circuits. World Journal of Condensed Matter Physics, 4, 84–92. https://doi.org/10.4236/wjcmp.2014.42013

[4] Dieng, A., Zerbo, I., Wade, M., Maiga, A.S., Sissoko, G. (2011). Three-Dimensional Study of a Polycrystalline Silicon Solar Cell: The Influence of the Applied Magnetic Field on the Electrical Parameters. Semiconductor Science and Technology, 26, 095023. https://doi.org/10.1088/0268-1242/26/9/095023

[5] Ouedraogo, A., Ky, T.S.M., Compaore, A., Bathiebo, D.J. (2019). Improvement in the Silicon Solar Cell Performance by Integration of the Electric Field Source in the Solar Cell Under Sunlight Illumination. Arabian Journal for Science and Engineering, 44, 6651–6657. https://doi.org/10.1007/s13369-019-03906-7

[6] Ouedraogo, I., et al. (2021). Investigation of the Polycrystalline Silicon PV Cell Efficiency in 3D Approximation versus Electromagnetic Field under Monochromatic Illumination. International Journal of Photoenergy, 2021, 5171351. https://doi.org/10.1155/2021/5171351

[7] Boiro, M., et al. (2022). Influence of the Magnetic Field on the Diffusion Capacitance of a Serial Vertical Junction Silicon Solar Cell in Frequency Modulation. American Journal of Modern Physics, 11(1), 1–6. https://doi.org/10.11648/j.ajmp.20221101.11

[8] Şahin, G., Rüstemli, S. (2026). Influence of Base Depth on the Frequency-Dependent Impedance Characteristics of Vertical Silicon Solar Cells Using Dynamic Impedance Spectroscopy. International Journal of Energy Research, 2026, 7618204. https://doi.org/10.1155/er/7618204

[9] Khalis, M., Masrour, R. (2021). Predominant Range of Serial Resistance and Recombination Velocity at Different Concentration Levels: Vertical Multijunction Cell. Silicon, 14, 6107–6112. https://doi.org/10.1007/s12633-021-01374-z