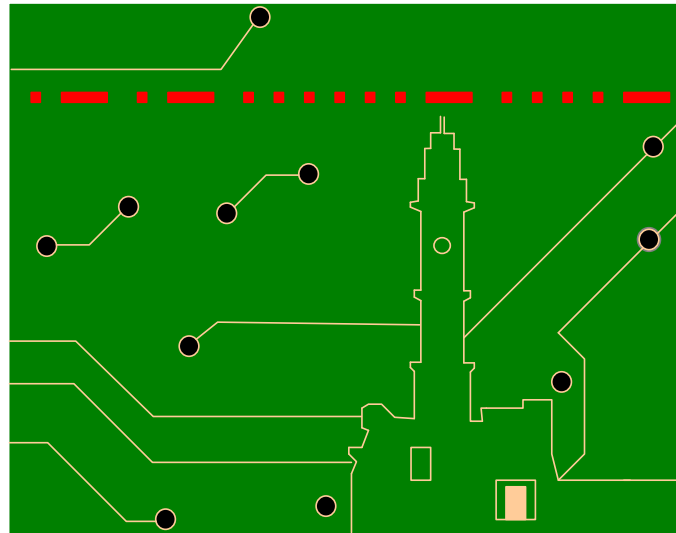


ΤΗΛ412 Ανάλυση & Σχεδίαση (Σύνθεση) Τηλεπικοινωνιακών Διατάξεων

Διαλέξεις 9-10



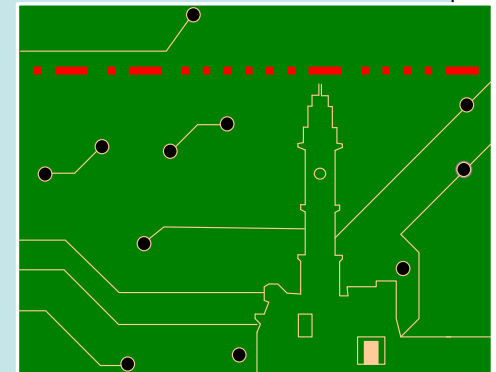
Άγγελος Μπλέτσας

ΗΜΜΥ Πολυτεχνείου Κρήτης, Χειμερινό Εξάμηνο
2016-2017

Διαλέξεις 9-10 – Κεραίες

(Από την οπτική γωνία του μηχανικού!)

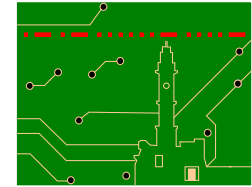
- Εξισώσεις Helmholtz & Maxwell (& διανυσματική ανάλυση).
- Σύζευξη μακρινού πεδίου (Far Field Coupling).
- Χαρακτηριστικά Κεραίων: VSWR, RL, Efficiency, Gain, Bandwidth, HPBW, Polarization.
- Γρήγορος υπολογισμός κέρδους σε κεραίες υψηλού κέρδους
- Κακή προσαρμογή Πόλωσης (Polarization Mismatch)



Βιβλιογραφία Διάλεξης

Kai Chang, “RF and Microwave Wireless Systems”, Wiley Series in Microwave and Optical Engineering, John Wiley & Sons, 2000.

Βασική ερώτηση μαθήματος



RADIO NEWS FOR FEBRUARY, 1934 403

LEARN RADIO FROM REAL RADIO ENGINEERS

HERE THEY ARE:
 Dr. C. V. Mackintosh, Chief Radio Engineer, General Electric Company
 (Waltham, Mass.)
 Kenneth Lynch, Chief Engineer, Radio Division, General Electric Company
 (Waltham, Mass.)
 Earl Hunt, Chief Engineer, Radio Division, General Electric Company
 (Waltham, Mass.)
 Harry Hogan, Chief Engineer, Radio Division, General Electric Company
 (Waltham, Mass.)
 R. W. Condon, Chief Engineer, Radio Division, General Electric Company
 (Waltham, Mass.)
 R. C. Tuller, Chief Engineer, Radio Division, General Electric Company
 (Waltham, Mass.)
 F. D. Williams, Chief Engineer, Radio Division, General Electric Company
 (Waltham, Mass.)

LET THESE ENGINEERS RIGHT FROM THE HEART OF THE BIG RADIO INDUSTRY Train You at Home for **GOOD PAY RADIO WORK** MANY R. T. I. TRAINED MEN MAKE \$35 TO \$75 A WEEK

If you're dissatisfied with small pay—work that's getting you nowhere—lay-off and uncertain income—here's an opportunity that's too good to miss. At the cost of only the time it takes you to mail the coupon, you can get my big FREE book, "RADIO'S FUTURE AND YOURS." This book tells how you can learn at home to make more money almost at once in Radio—whether you want to make Radio your life's work, or use it to pick up an extra \$5 to \$20 a week in your spare time.

"RADIO IS CROWDING BY LEAPS AND BOUNDS!"
 says Radio Craft Magazine. It has forged ahead even in depression years. Where only a few hundred men were employed a short time ago, thousands are employed today. Where a few years ago a hundred jobs paid \$35 to \$75 a week—there are thousands of such jobs today. And more new jobs being created all the time—full time jobs and spare time jobs. Get my book and see how easy it is to learn at home for this good-pay work.

R. T. I. TRAINING IS "SHOP TRAINING" FOR THE HOME
 It comes to you right from the Radio Industry—right out of the factories where Radio sets and other vacuum-tube devices are made. It was planned and prepared for you by big radio engineers in these factories, most of whom are the Chief Engineers of these great Radio plants. And NOW these same engineers are actually supervising R-T-I Training. Which means that trained the R-T-I way you'll be trained as the Radio Industry wants you trained—as just as the Radio Industry itself would train you if it was doing the job.

4 BIG WORKING OUTFITS INCLUDED
 These are probably the biggest and most expensive Working Outfits ever included with a home-training course. You are then to build up testing equipment—to experiment with—to do actual Radio work. It's Shop Training for the home.

SOUND PICTURES, P. A. SYSTEMS, PHOTO CELLS, TELEVISION, ETC. ALL INCLUDED
 Radio service work is just the starting point in R-T-I Training. From there we take you up through the very latest developments in Radio, and then on into the new and larger field of Electronics—Sound Pictures, Public Address Systems, Photo Cells, and Television. This feature alone makes R-T-I the outstanding home training in Radio.

YOU GET "QUICK RESULTS!"
 C. E. Head, 51 Third St., Alexandria, La., says: "While my first money, I took after receiving your training—cleared \$142."
 Frank E. Alexander, Lake Ill., writes: "Doubtful my pay is less than six months."
 Harry L. Stark, Ft. Wayne, Ind., writes: "Now making three times as much money as I was when I started your training."

AGE OR LACK OF EDUCATION NO HANDICAP
 You don't have to be a high school graduate. It isn't necessary that you should have finished the grades. My Training in Radio is so simple, so easy, and so practical, that it offers every man, regardless of age, education, or previous experience, the chance to get out of a small-pay, menial job, into good pay, big future work in Radio.

YOUR MONEY BACK IF YOU ARE NOT SATISFIED
 That's my way of doing business. And I'll give you that agreement in writing—an agreement to refund every penny of your tuition if, on completion of my Training, you are not entirely satisfied.

INVESTIGATE! Learn why R-T-I Training is different. Find out why R-T-I Trained men get "Quick Results" and "Big Results." Send today for my big book "Radio's Future and Yours." The book is free.
 RAY D. SMITH, President
 Radio & Television Institute, Chicago



RADIO and TELEVISION INSTITUTE HOME TRAINING

say these **30** Leading Radio Manufacturers and they are talking to YOU

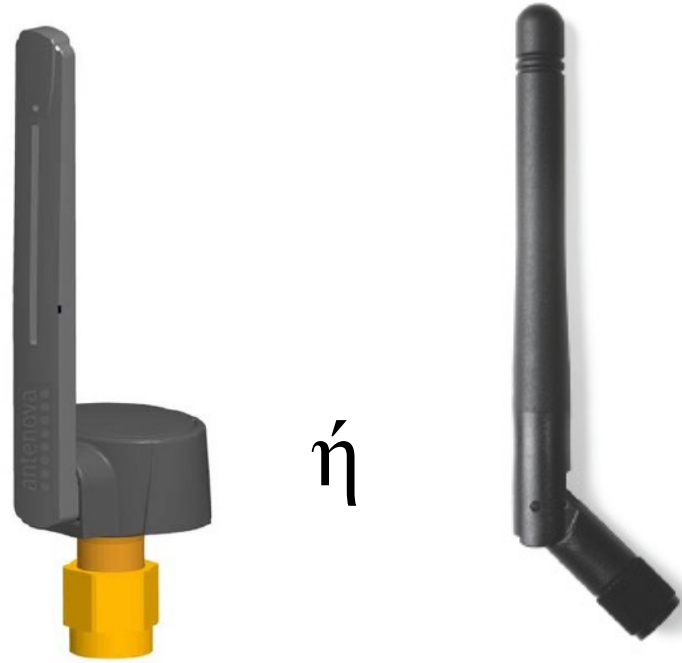
- AMERICAN TELEVISION
- ARCTURUS TUBES
- BALKBIT • BRUNSWICK
- CAPEHART
- CLOUGH-BRENGLE CO.
- CLARION • CLARION
- DeFOREST • ECHOPHONE
- FADA • GREBE • HOWARD
- HAMMERLUND • HICKOK
- INTERNATIONAL
- RESISTANCE CO.
- KENNEDY • KOLSTER • LYRIC
- MAJESTIC • PHILCO
- RADIO PRODUCTS CO.
- SANGAMO ELECTRIC
- SENTINEL • SHELDON
- SILVER-MARSHALL CO.
- STEWART-WARNER
- STROMBERG-CARLSON
- UNIVERSAL MICROPHONE
- ZENITH

MAIL COUPON FOR MY FREE BOOK

On your copy of "Radio's Future and Yours" I enclose you a coupon for my free book "Radio's Future and Yours." I am interested in your home training and the opportunity you see with the great field of Radio for the R. T. I. Trained man.

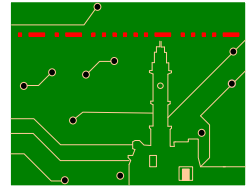
Ray D. Smith, President
 RADIO AND TELEVISION INSTITUTE, (R. T. I.)
 258 Lawrence Ave., Dept. 41, Chicago, Ill.
 Without obligation on my kind please send me a copy of "Radio's Future and Yours." I am interested in your home training and the opportunity you see with the great field of Radio for the R. T. I. Trained man.

Name _____
 Address _____
 City _____ State _____

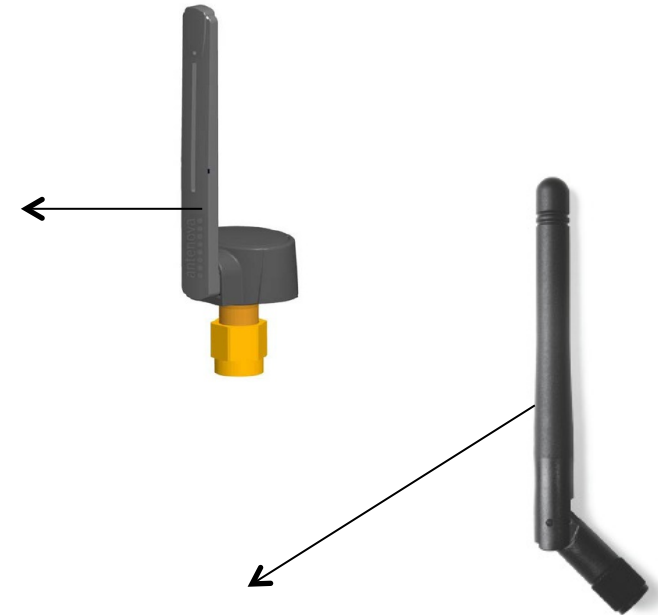


ή ?

Κεραίες 2.4-2.5GHz



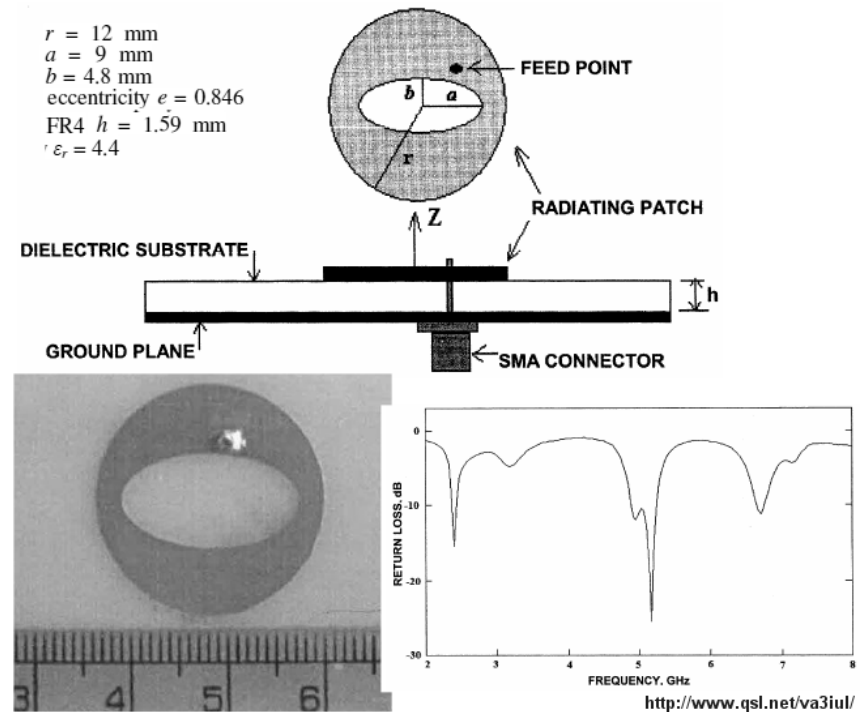
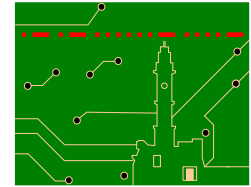
	Typical performance
Peak gain	2.2 dBi
Average gain	-1.0 dBi
Average efficiency	80%
Maximum Return Loss	-13 dB
Maximum VSWR	1.6:1

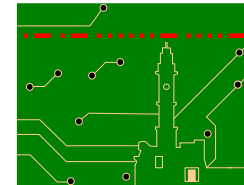


Frequency [GHz]	Gain [dBi]	Impedance [Nom]	VSWR	Polarization	Electrical Length	Radiation
2.4 – 2.5	2.0	50 Ω	≤ 2.0	Vertical	$\frac{1}{4}$, dipole	Omni

Ορισμός

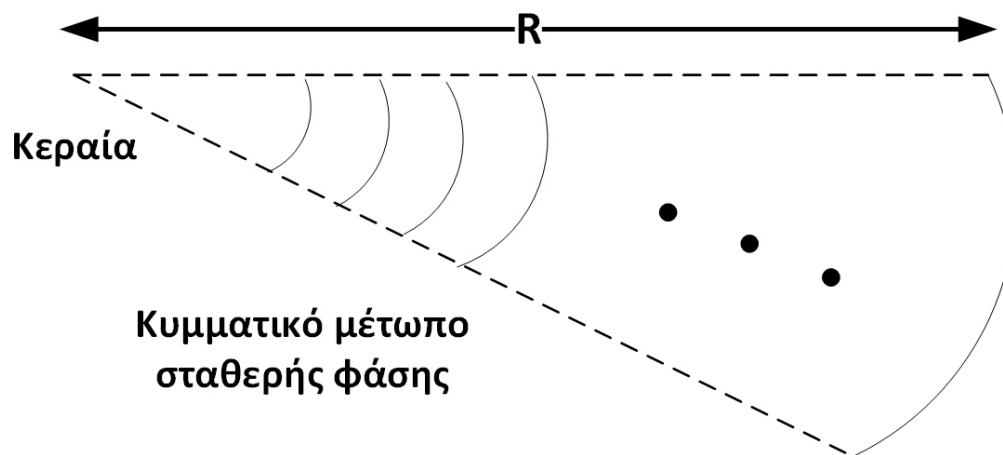
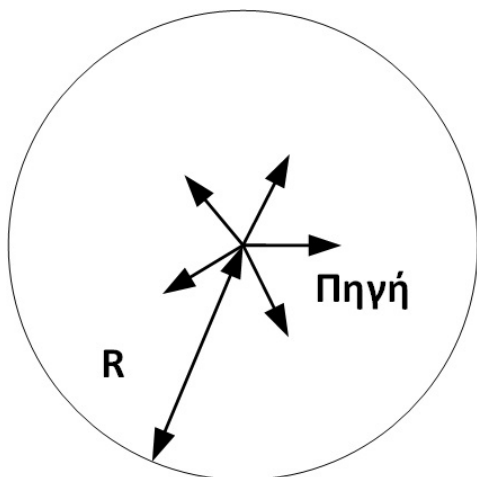
- Κεραία = διεπαφή (i.e. interface) μεταξύ κυμάτων/σημάτων.
- Κεραία \equiv συντονισμός.
- Κεραία = μέγιστη ακτινοβολία.
- Κυματοδηγός = ελάχιστη ακτινοβολία.
- Χαρακτηρισμός: γεωμετρία, κέρδος, λωβός, εύρος ζώνης.





Ισοτροπικός Ακτινοβολητής και Επίπεδα Κύματα

$$\nabla^2 \vec{E} + k_0^2 \vec{E} = 0$$

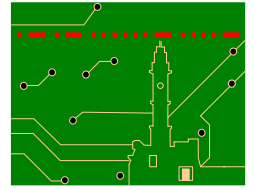


- Θεωρητικό (και μόνο) εργαλείο.
- Μέτωπο κύματος σφαιρικό.
- Πυκνότητα ισχύος:

$$P_d = \frac{P_t}{4\pi \cdot R^2}$$

- Μεγάλο $R \Rightarrow$ επίπεδο κύμα (όχι σφαιρικό)
- Η/Μ πεδίο: Εξίσωση Κύματος (Helmholtz).

Θυμάστε τις εξισώσεις του Maxwell?



Div: Μεταβολή διανυσματικού πεδίου ανά μονάδα όγκου

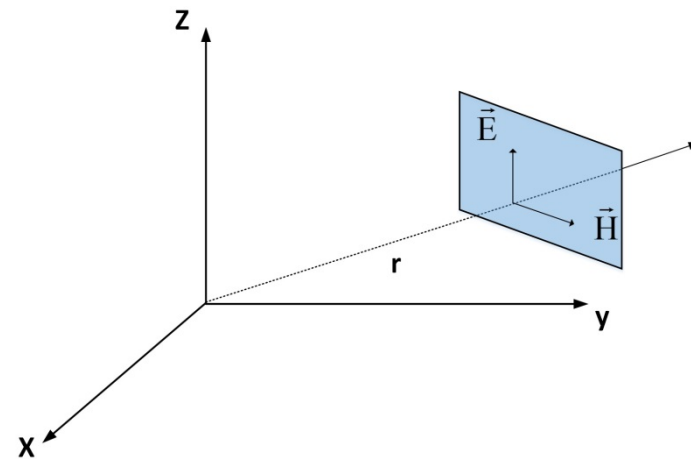
↙

$$\nabla \cdot \vec{E} = \frac{\rho}{\epsilon} \quad \text{Gauss' law}$$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \quad \text{Faraday's law}$$

$$\nabla \times \vec{H} = \frac{\partial \vec{D}}{\partial t} + \vec{J} \quad \text{Ampere's law}$$

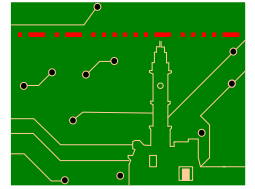
$$\nabla \times \vec{B} = 0 \quad \text{flux law}$$



↘

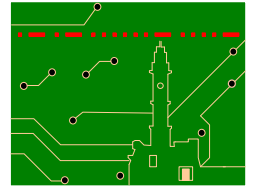
Curl: Στροβιλισμός διανυσματικού πεδίου ανά μονάδα επιφάνειας

Βασικές Η/Μ Μονάδες



- Διηλεκτρική σταθερά (permittivity) ϵ : Farad/m
- Ηλεκτρικό πεδίο (Electric Field) E : Volt/m
- Μαγνητική διαπερατότητα (permeability) μ : Henry/m
- Μαγνητικό πεδίο (Magnetic Field) H : Ampere/m
- Πυκνότητα μαγνητικής ροής (Magnetic flux density) B : Tesla
- Μαγνητική ροή (Magnetic flux) Φ : Weber = Henry Ampere
- Ηλεκτρική μετατόπιση (Electric Displacement) D : Coulomb/m²

Θυμάστε διανυσματική ανάλυση?



Let $f: \mathbb{R}^3 \rightarrow \mathbb{R}^3$ and $F: \mathbb{R}^3 \rightarrow \mathbb{R}^3$. Write $F = (f_1, f_2, f_3)$.

Similarly for g and G .

Define:

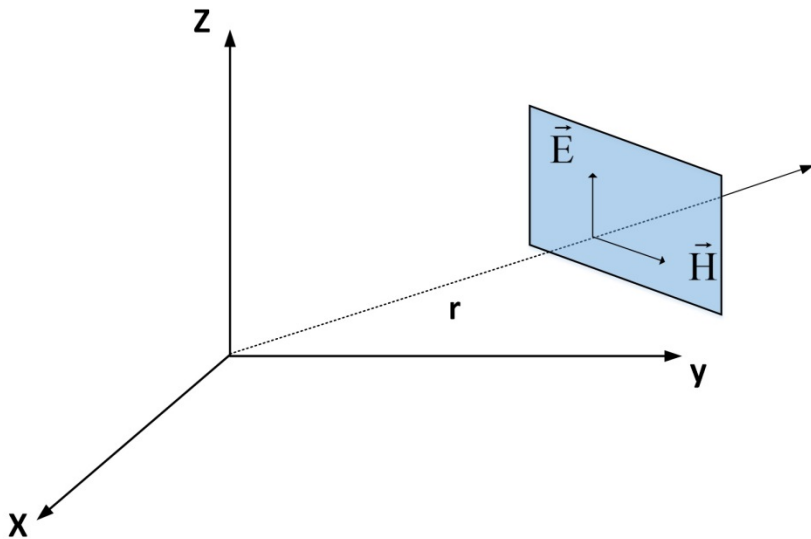
$$\text{grad}(f) \equiv \nabla f = \left(\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}, \frac{\partial f}{\partial z} \right)$$

$$\text{div}(F) \equiv \nabla \cdot F = \frac{\partial f_1}{\partial x} + \frac{\partial f_2}{\partial y} + \frac{\partial f_3}{\partial z}$$

$$\text{curl}(F) \equiv \nabla \times F = \left(\frac{\partial f_3}{\partial y} - \frac{\partial f_2}{\partial z}, \frac{\partial f_1}{\partial z} - \frac{\partial f_3}{\partial x}, \frac{\partial f_2}{\partial x} - \frac{\partial f_1}{\partial y} \right)$$

$$\text{laplace}(f) \equiv \nabla^2 f = \left(\frac{\partial^2 f}{\partial x^2}, \frac{\partial^2 f}{\partial y^2}, \frac{\partial^2 f}{\partial z^2} \right)$$

$$\text{laplace}(F) \equiv \nabla^2 F = \left(\nabla^2 f_1, \nabla^2 f_2, \nabla^2 f_3 \right)$$



Θυμάστε διανυσματική ανάλυση?

Let $\phi(x,y,z)$ be a scalar field. The gradient is a vector

$$\text{grad } \phi = \left(\frac{\partial \phi}{\partial x}, \frac{\partial \phi}{\partial y}, \frac{\partial \phi}{\partial z} \right),$$

it is the derivative of ϕ in each direction. The gradient of a scalar field is a vector field. An alternative notation is to use the *del* or *nabla* operator, $\nabla \phi = \text{grad } \phi$.

Divergence of a vector field

Let $F(x,y,z)$ be a vector field, continuously differentiable with respect to x,y and z . Then the divergence of F is defined by

$$\text{div } F = \frac{\partial F_1}{\partial x} + \frac{\partial F_2}{\partial y} + \frac{\partial F_3}{\partial z}.$$

Laplacian



$$\Delta f = \nabla^2 f = \nabla \cdot \nabla f,$$

$$\Delta f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2} + \frac{\partial^2 f}{\partial z^2}$$

div F is a scalar field it can also be written as $\text{div } \mathbf{F} = \nabla \cdot \mathbf{F}$

$$\Delta f = \frac{1}{\rho} \frac{\partial}{\partial \rho} \left(\rho \frac{\partial f}{\partial \rho} \right) + \frac{1}{\rho^2} \frac{\partial^2 f}{\partial \theta^2} + \frac{\partial^2 f}{\partial z^2}$$

Curl of a vector field

$$\Delta f = \frac{1}{r^2} \frac{\partial}{\partial r} \left(r^2 \frac{\partial f}{\partial r} \right) + \frac{1}{r^2 \sin \varphi} \frac{\partial}{\partial \varphi} \left(\sin \varphi \frac{\partial f}{\partial \varphi} \right) + \frac{1}{r^2 \sin^2 \varphi} \frac{\partial^2 f}{\partial \theta^2}$$

Let $F(x,y,z)$ be a vector field, continuously differentiable with respect to x,y and z . Then the **curl** of F is defined by

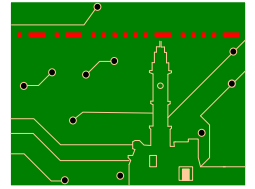
$$\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ F_1 & F_2 & F_3 \end{vmatrix}$$

$$= \text{curl } F = \left(\frac{\partial F_3}{\partial y} - \frac{\partial F_2}{\partial z} \right) \mathbf{i} - \left(\frac{\partial F_3}{\partial x} - \frac{\partial F_1}{\partial z} \right) \mathbf{j} + \left(\frac{\partial F_2}{\partial x} - \frac{\partial F_1}{\partial y} \right) \mathbf{k}$$

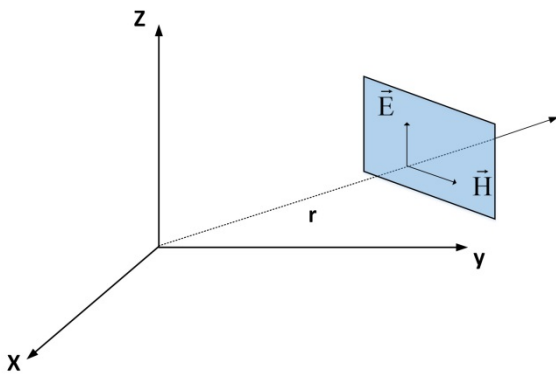
curl F is a vector field it can also be written as $\nabla \times F$.

Notice that $\nabla \cdot (\nabla \times \mathbf{F}) = 0$

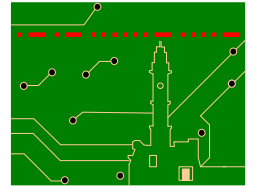
Θυμάστε διανυσματική ανάλυση?



$$\begin{aligned} \text{grad}(f + g) &\equiv \nabla(f + g) = \nabla f + \nabla g \\ \text{div}(\mathbf{F} + \mathbf{G}) &\equiv \nabla \cdot (\mathbf{F} + \mathbf{G}) = \nabla \cdot \mathbf{F} + \nabla \cdot \mathbf{G} \\ \text{curl}(\mathbf{F} + \mathbf{G}) &\equiv \nabla \times (\mathbf{F} + \mathbf{G}) = \nabla \times \mathbf{F} + \nabla \times \mathbf{G} \\ \text{grad}(fg) &\equiv \nabla(fg) = f\nabla g + g\nabla f \\ \text{div}(f\mathbf{G}) &\equiv \nabla \cdot (f\mathbf{G}) = \nabla f \cdot \mathbf{G} + f\nabla \cdot \mathbf{G} \\ \text{curl}(f\mathbf{G}) &\equiv \nabla \times (f\mathbf{G}) = \nabla f \times \mathbf{G} + f\nabla \times \mathbf{G} \\ \text{grad}(\mathbf{F} \cdot \mathbf{G}) &\equiv \nabla(\mathbf{F} \cdot \mathbf{G}) = (\mathbf{F} \cdot \nabla)\mathbf{G} - (\mathbf{G} \cdot \nabla)\mathbf{F} + \mathbf{F} \times (\nabla \times \mathbf{G}) + \mathbf{G} \times (\nabla \times \mathbf{F}) \\ \text{div}(\mathbf{F} \times \mathbf{G}) &\equiv \nabla \cdot (\mathbf{F} \times \mathbf{G}) = \mathbf{G} \cdot \nabla \times \mathbf{F} - \mathbf{F} \cdot \nabla \times \mathbf{G} \\ \text{curl}(\mathbf{F} \times \mathbf{G}) &\equiv \nabla \times (\mathbf{F} \times \mathbf{G}) = \mathbf{F}(\nabla \cdot \mathbf{G}) - \mathbf{G}(\nabla \cdot \mathbf{F}) + (\mathbf{G} \cdot \nabla)\mathbf{F} - (\mathbf{F} \cdot \nabla)\mathbf{G} \\ \text{div grad } f &= \nabla \cdot \nabla f = \nabla^2 f = \text{laplace } f \\ \text{curl grad } f &= \nabla \times \nabla f = 0 \\ \text{div curl } \mathbf{F} &= \nabla \cdot (\nabla \times \mathbf{F}) = 0 \\ \text{curl}^2 \mathbf{F} &= \nabla \times (\nabla \times \mathbf{F}) = \nabla \nabla \cdot \mathbf{F} - \nabla^2 \mathbf{F} = \text{grad div}(\mathbf{F}) - \text{laplace } \mathbf{F} \\ \text{grad div } \mathbf{F} &= \nabla \nabla \cdot \mathbf{F} = \nabla \times (\nabla \times \mathbf{F}) + \nabla^2 \mathbf{F} = \text{curl}^2 \mathbf{F} + \text{laplace } \mathbf{F} \end{aligned}$$



Θυμάστε διανυσματική ανάλυση?(2)



Τα παρακάτω video εξηγούν την διαίσθηση (intuition)...
(curl=περιστροφή/ροπή διανύσματος σε σχέση με επιφάνεια,
div=ρυθμός μεταβολής διανύσματος σε σχέση με όγκο,
grad= κατεύθυνση ρυθμού μεταβολής)

Curl

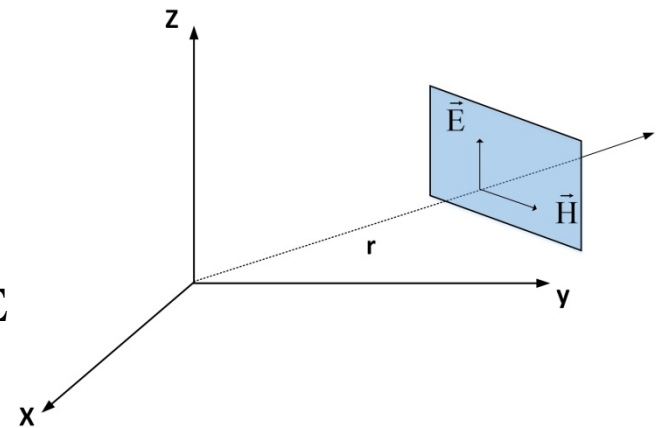
<http://www.youtube.com/watch?v=fYzoiWIBjP8>

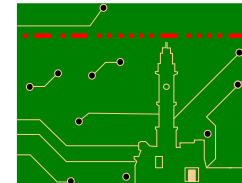
Div

<http://www.youtube.com/watch?v=tOX3RkH2guE>

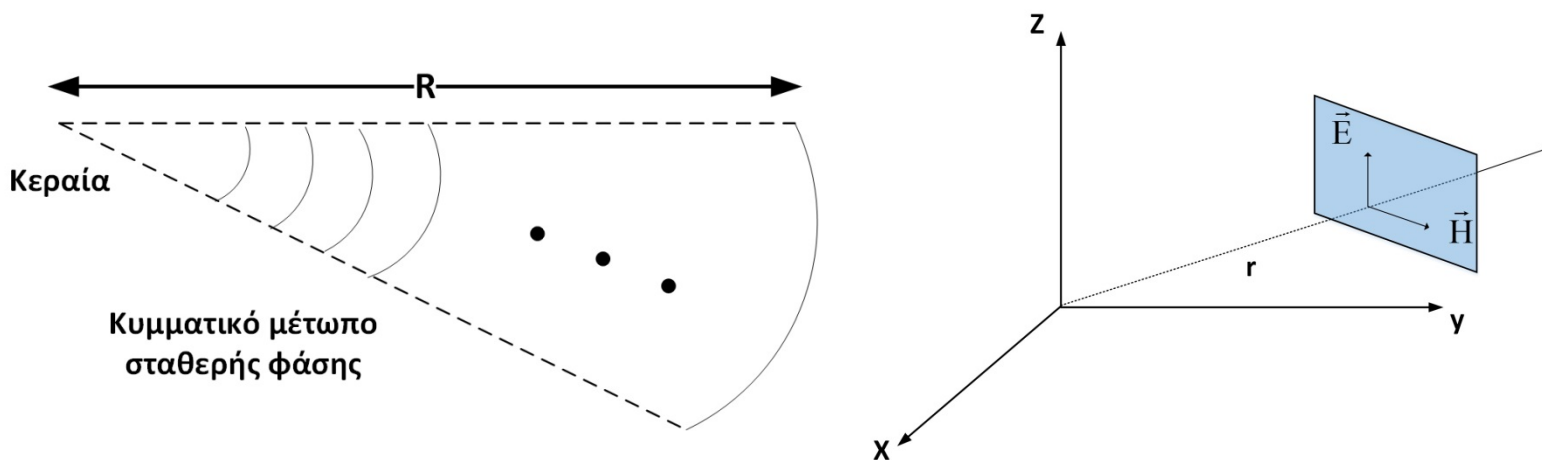
Grad

<http://www.youtube.com/watch?v=OB8b8aDGLgE>





Εξίσωση Κύματος (Εξίσωση Helmholtz): Επίλυση



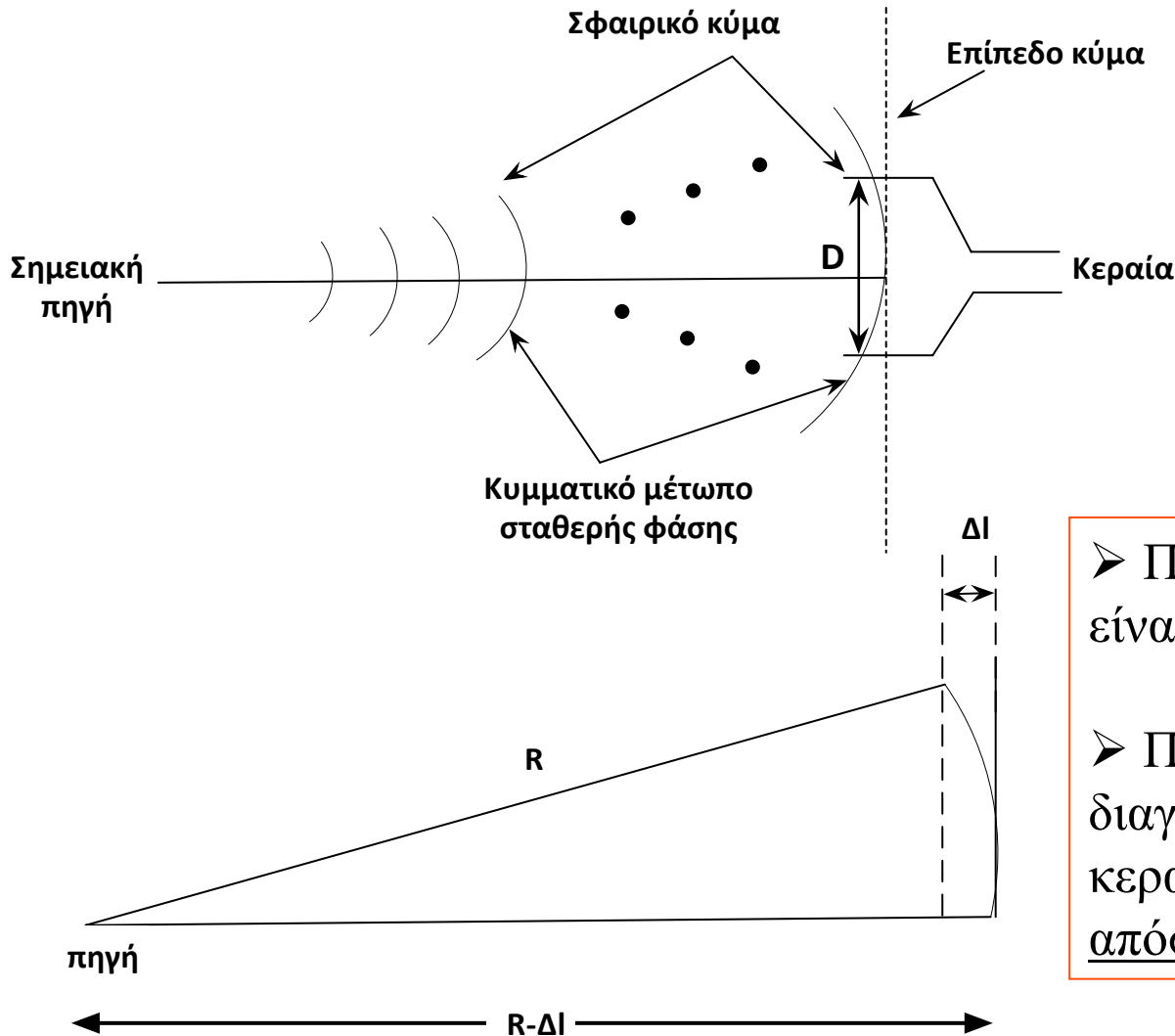
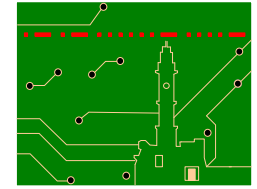
$$k_0 = \frac{2\pi}{\lambda_0}, \vec{k}_0 = k_0 \vec{n}_0, \quad \vec{H} = -\frac{1}{j\omega \mu_0} \nabla \times \vec{E} = \sqrt{\frac{\epsilon_0}{\mu_0}} \vec{n} \times \vec{E}. \quad \text{Maxwell}$$

$$\vec{E} = \vec{E}_0 e^{-j\vec{k}_0 \cdot \vec{r}}, \quad \eta_0 = \frac{|\vec{E}|}{|\vec{H}|} = \sqrt{\frac{\mu_0}{\epsilon_0}} = 120\pi \quad \leftarrow \text{Διαστάσεις σε } \Omega\text{m}$$

Λύση Helmholtz

$$P_d = \left| \frac{1}{2} \vec{E} \times \vec{H}^* \right| = \frac{1}{2} \frac{E_0^2}{\eta_0} = \frac{P_t}{4\pi R^2} \Rightarrow E_0 = \frac{\sqrt{60P_t}}{R} = \sqrt{2} E_{\text{rms}}$$

Περιοχή Μακρινού Πεδίου (Far Field Region)



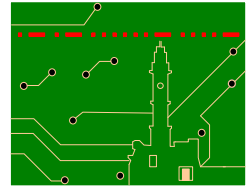
$$R^2 = (R - \Delta l)^2 + \frac{D^2}{4}, R^2 \approx R^2 + (\Delta l)^2 \Rightarrow$$

$$R = \frac{D^2}{8\Delta l}, \Delta l = \frac{1}{16} \lambda_0 \Rightarrow$$

$$R_{\text{far-field}} = \frac{2D^2}{\lambda_0}$$

- Περιοχή όπου το επίπεδο κύμα είναι “καλή” προσέγγιση!
- Πρακτικά, εκεί όπου τα διαγράμματα ακτινοβολίας των κεραιών είναι ανεξάρτητα της απόστασης.

Χαρακτηριστικά: Input VSWR & Impedance



Αποδεικνύονται στις επόμενες διαλέξεις

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|},$$

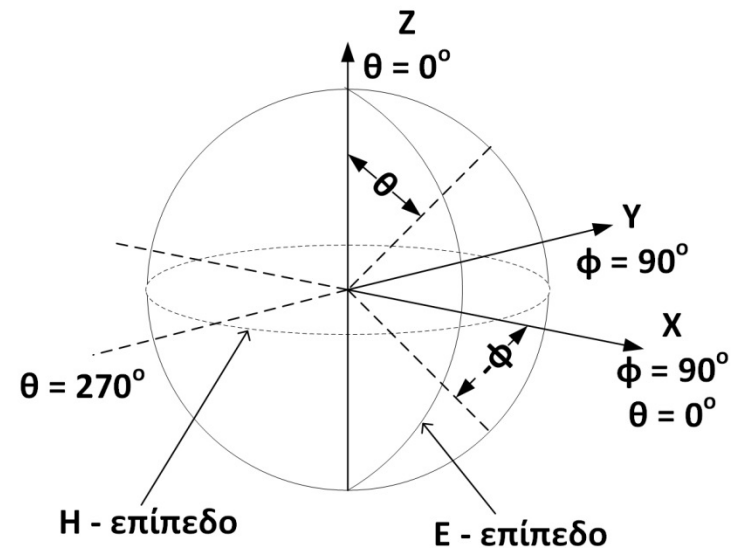
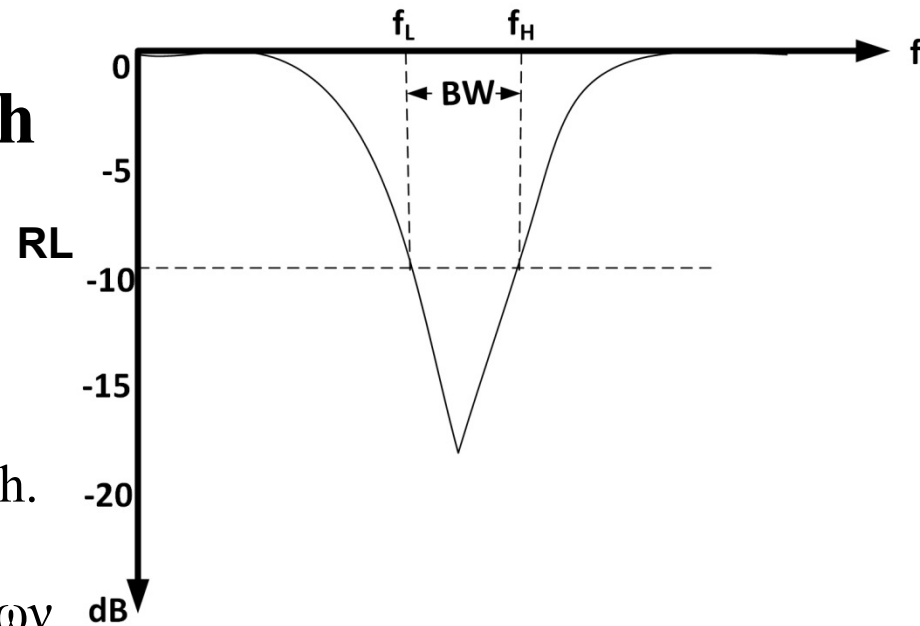
$$RL = 20\log_{10} |\Gamma|, \quad \text{Return Loss}$$

$$Z_{in} = Z_0 \frac{1+\Gamma}{1-\Gamma}.$$

- $|\Gamma|^2$: ποσοστό ισχύος που χάνεται λόγω κακής προσαρμογής (και ανάκλασης).
- ισχύς στην κεραία = $(1-|\Gamma|^2)$ φορές την ισχύ που παραδίδει η πηγή.
- Συνήθως, VSWR είναι μικρότερο του 2:1.
- Παράδειγμα: VSWR = 2:1 σημαίνει ότι $|\Gamma|^2 = 11\%$ της παραδιδόμενης ισχύος στην κεραία χάνεται και δεν εκπέμπεται (λόγω κεραίας)!

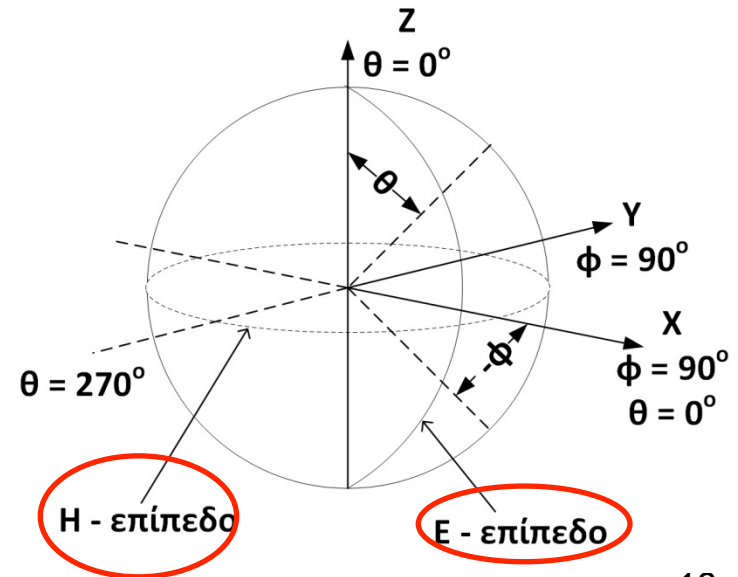
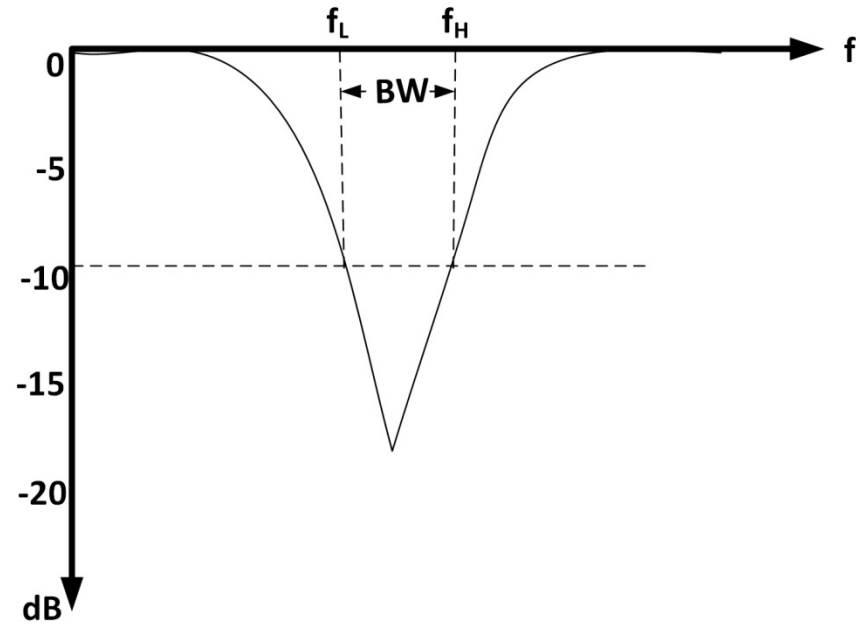
Χαρακτηριστικά: Bandwidth

- Πολλαπλοί ορισμοί, ανάλογα με την εφαρμογή.
- Πιο συνηθισμένη: impedance bandwidth.
- Impedance bandwidth: εύρος συχνοτήτων όπου RL είναι κάτω από ένα όριο.
- Άλλοι ορισμοί βασίζονται σε κέρδος (gain), απόδοση (efficiency), διαγράμματα (patterns) etc.
- Λειτουργικό εύρος ζώνης συνήθως μικρότερο.

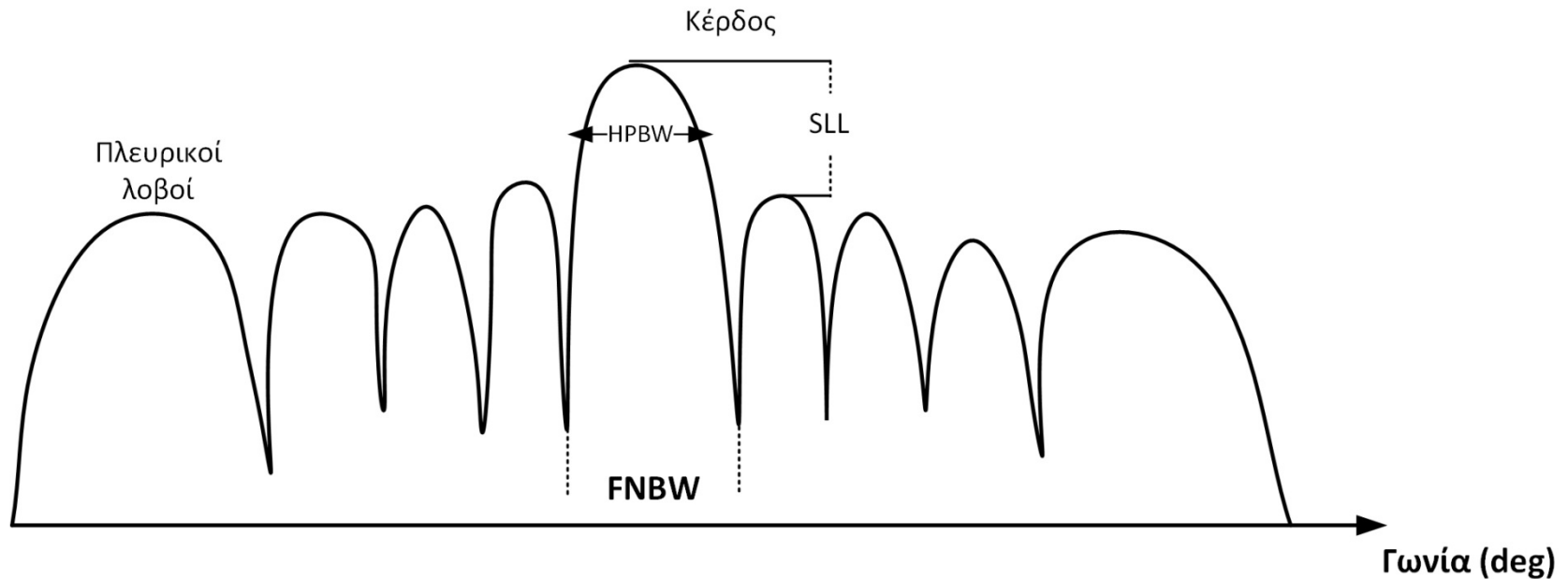
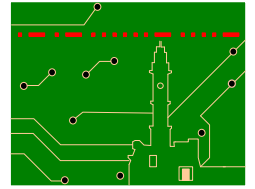


Χαρακτηριστικά: Διαγράμματα Ακτινοβολίας

- Θυμηθείτε: ηλεκτρικά χαρακτηριστικά μακρινού πεδίου είναι ανεξάρτητα της απόστασης.
- Τυπικά, διαγράμματα πυκνότητας ισχύος (διάνυσμα Poynting διαμέσου μιας σφαίρας με κέντρο την κεραία).
- Απλούστερη προσέγγιση: σχεδίαση ηλεκτρικού ή/και μαγνητικού πεδίου σε επίπεδα τομής όπου το πεδίο μεγιστοποιείται.
- E-plane: E_θ plane.
- Cross-polarization component: E_ϕ

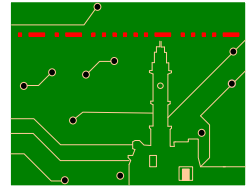


Χαρακτηριστικά: Εύρος δέσμης κεραίας Ημίσειας-Ισχύος (Half-Power Beamwidth-HPBW) και Επίπεδο Πλευρικού Λοβού (Side Lobe Level - SLL)



- HPBW: το εύρος σε μοίρες ώστε η ισχύς ακτινοβολίας να πέσει στο μισό.
- SLL: ο αριθμός σε dB κάτω από τον κύριο λοβό των πλευρικών λοβών.

Χαρακτηριστικά: Κατευθυντικότητα (Directivity), Κέρδος (Gain), Απόδοση (Efficiency)



$$\text{Poynting power density} = \vec{S}(\theta, \varphi) = \frac{1}{2} \Re[\vec{E} \times \vec{H}^*],$$

$$D(\theta, \varphi) = \frac{S(\theta, \varphi)}{\cancel{P_t}/4\pi R^2},$$

$$D_{\max} = \frac{\max|\vec{S}(\theta, \varphi)|}{\cancel{P_t}/4\pi R^2},$$

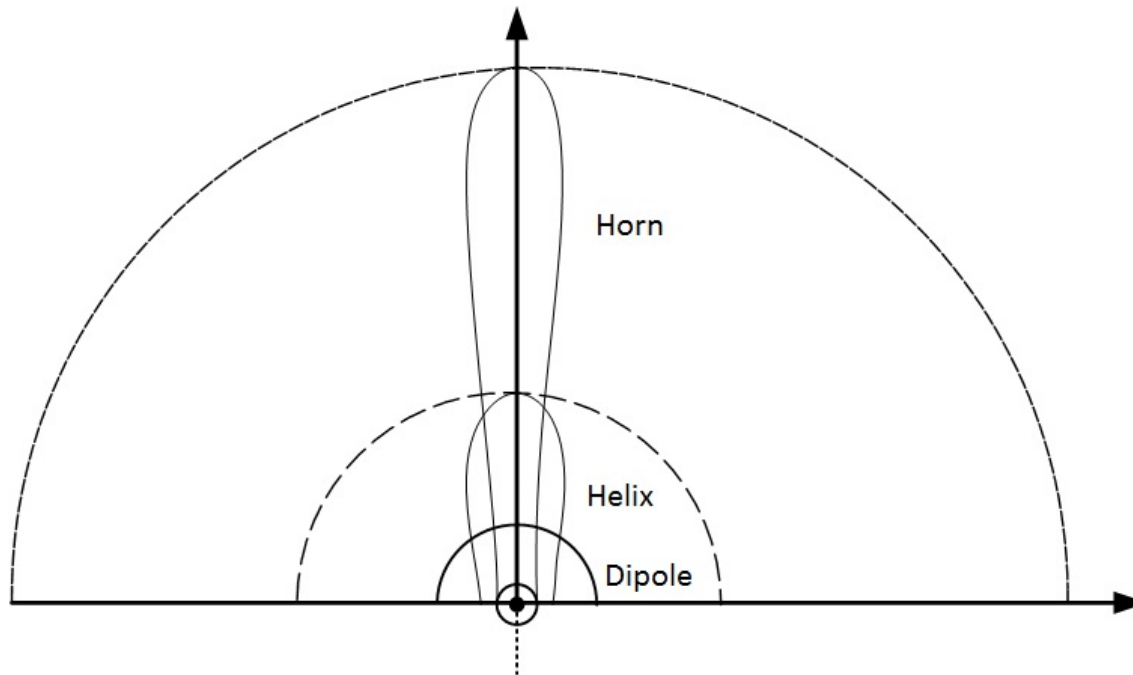
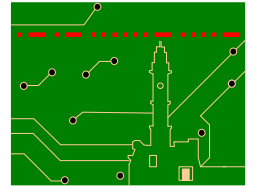
Note: $P_t = P_{\text{rad}}$

$$\text{efficiency } \eta = \frac{P_{\text{rad}}}{P_{\text{in}}} = \frac{P_{\text{rad}}}{P_{\text{rad}} + P_{\text{loss}}}.$$

$$\text{Gain } G = \eta D_{\max}.$$

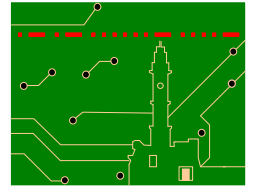
- Κέρδος και απόδοση συνδέουν ακτινοβολούμενη ισχύ με ισχύ εισόδου (στην κεραία).
- Για παράδειγμα: $G P_{\text{in}}/4\pi R^2$ είναι ακτινοβολούμενη πυκνότητα ισχύος στην κατεύθυνση μέγιστης ακτινοβολίας (Σημ.: P_{in} είναι συνολική ισχύ εισόδου)
- $P_{\text{in}} = P_{\text{rad}} + P_{\text{loss}}$.
- Γιατί δεν μεγιστοποιούμε πάντα το κέρδος?

Χαρακτηριστικά: Κέρδος-εύρος ζώνης tradeoff



- Κέρδος-εύρος δέσμης tradeoff: μεγιστοποίηση του ενός, ελαχιστοποίηση του άλλου.
- Κέρδος-εύρος ζώνης (bandwidth) tradeoff υπάρχει επίσης και είναι θεμελιώδες.
- Επομένως, μεγιστοποίηση του κέρδους κεραίας κοστίζει σε μειωμένο εύρος ζώνης και αυξημένο SLL.

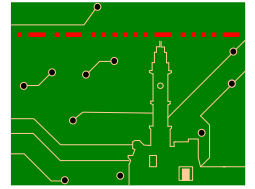
Χαρακτηριστικά: Γρήγορη Εκτίμηση Κέρδους σε Κεραίες Υψηλού Κέρδους



$$\text{HPBW} \approx K_1 \frac{\lambda_0}{D}, \quad G \approx \frac{K_2}{\theta_1 \theta_2}$$

- $K_1 \approx 70^\circ$, D διάσταση κεραίας στο επίπεδο ενδιαφέροντος.
- $K_2 \approx 30,000$, θ_1, θ_2 είναι HPBW σε δύο βασικά ορθογώνια επίπεδα.

Χαρακτηριστικά: Ενεργός επιφάνεια (Effective Area), Πόλωση (Polarization)

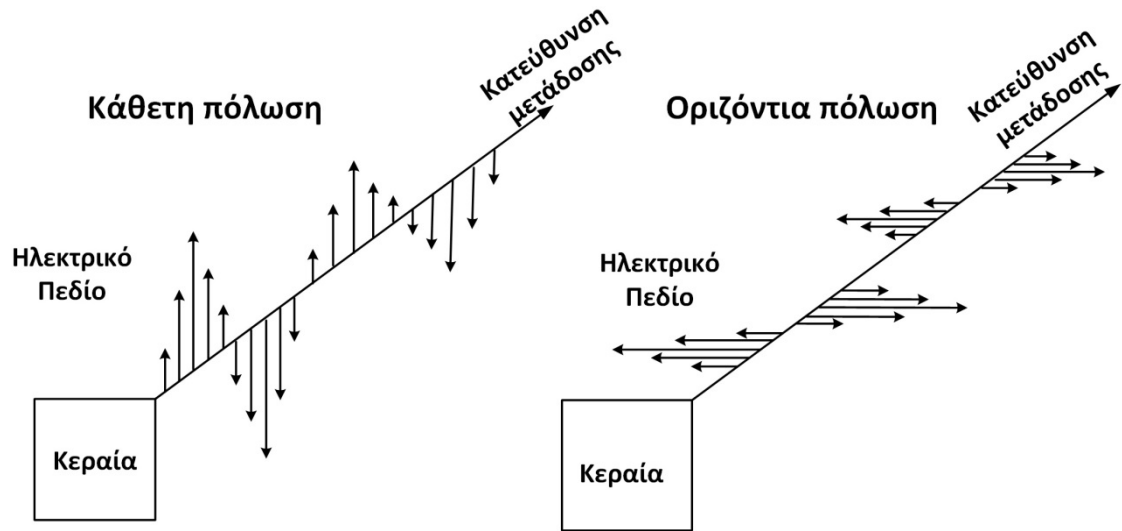
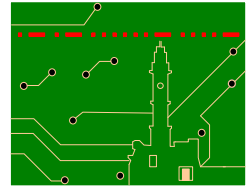


- Ενεργός επιφάνεια είναι ανάλογη (αλλά συνήθως μικρότερη) της φυσικής επιφάνειας της κεραίας.
- Η εξίσωση απωλειών ελευθέρου χώρου Friis βασίζεται στην ενεργό επιφάνεια A_e η οποία συνδέεται με το κέρδος βάση της παρακάτω:

$$G = \frac{4\pi}{\lambda^2} A_e$$

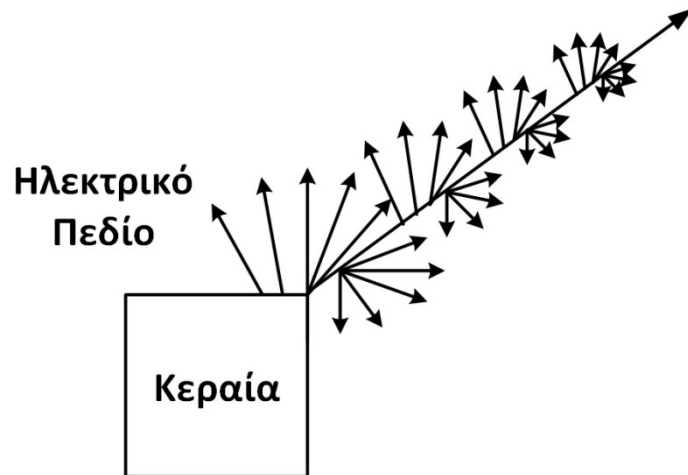
- Πόλωση = κατεύθυνση ηλεκτρικού πεδίου συναρτήσει του χρόνου:
 - ίσια γραμμή: γραμμική πόλωση (linear polarization),
 - κύκλος: κυκλική πόλωση [circular polarization, Left Hand (LH) ή Right Hand (RH)],
 - έλλειψη: ελλειπτική πόλωση (elliptical polarization).

Παράδειγμα Πόλωσης



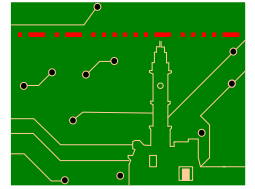
➤ γραμμική...

Κυκλική πόλωση δεξιού χεριού

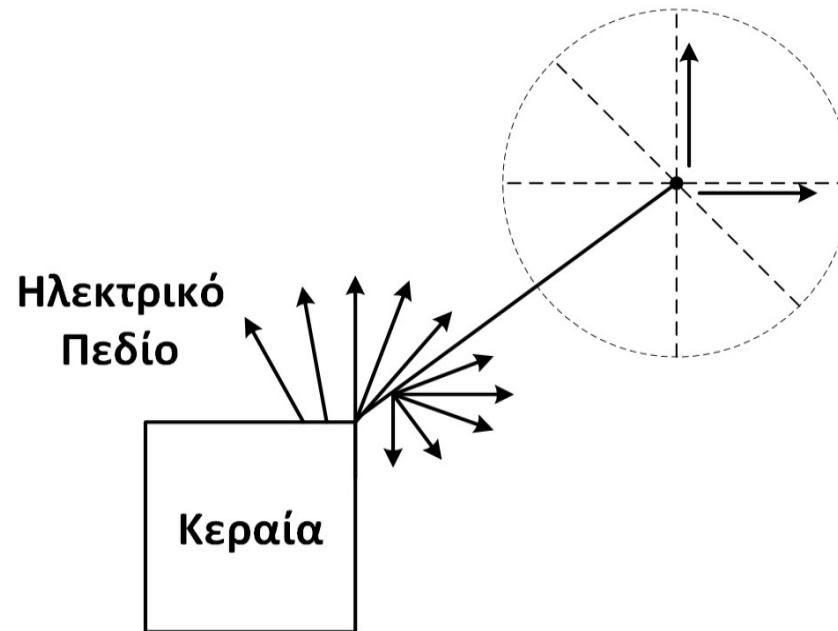


➤ κυκλική...

Κακή προσαρμογή Πόλωσης



Κάθε οριζόντια ή κάθετη
πόλωση λαμβάνει την μισή ισχύ



- Κυκλικά πολωμένη κεραία εκπέμπει σε γραμμικά πολωμένη κεραία λήψης.
- Η ισχύς λήψης είναι μειωμένη κατά 3 dB.

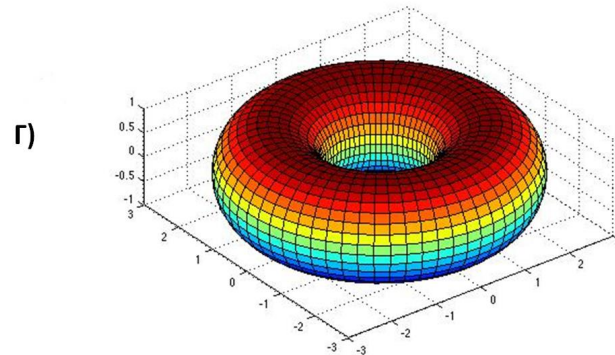
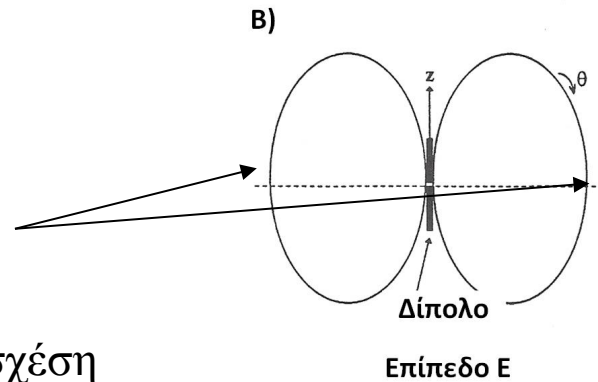
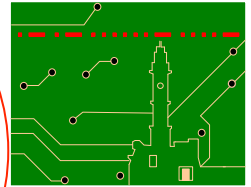
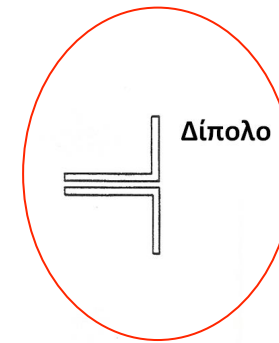
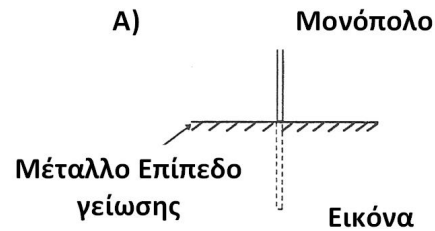
Παράδειγμα: Δίπολο

➤ $G = 1.64 \Rightarrow 2.15 \text{ dBi}$

➤ ERP: ισχύς εκπομπής σε σχέση με το κέρδος διπόλου.

➤ EIRP: ισχύς εκπομπής σε σχέση με το κέρδος (=1) ισοτροπικής κεραίας.

➤ dBc: κέρδος κεραίας αναφερόμενο σε κυκλικά πολωμένη κεραία.



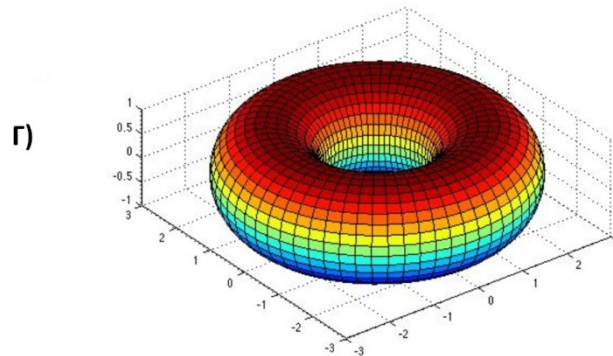
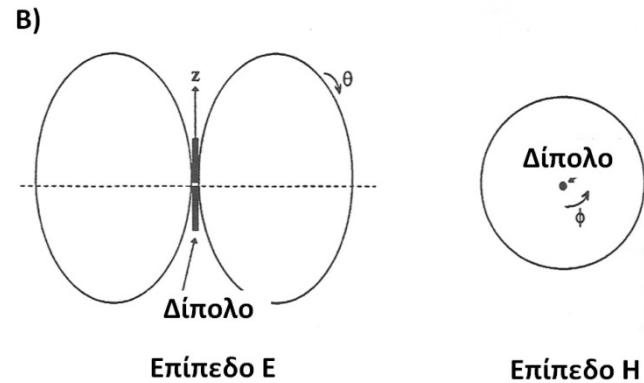
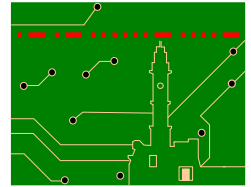
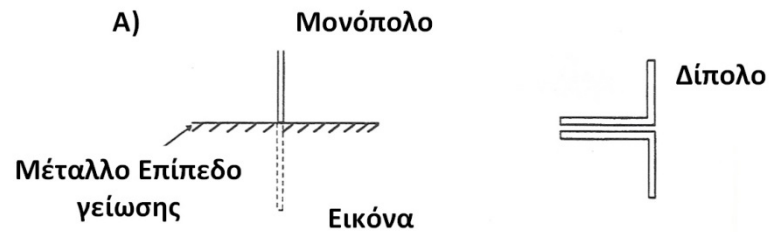
Παραδείγματα:

➤ δίπολο $G = 1.64 = 2.15 \text{ dBi}$

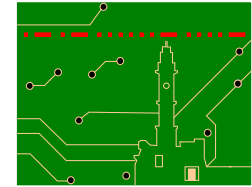
➤ $2 \text{ W ERP} = 2 \times 1.64 \text{ EIRP} = 35.15 \text{ dBm EIRP}$

➤ $G = 7 \text{ dBc} = 4 \text{ dBi}$

➤ $G = 7 \text{ dBd} = 9.15 \text{ dBi}$



Βασική ερώτηση μαθήματος



RADIO NEWS FOR FEBRUARY, 1934 403

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 Kenneth Lynch, Chief Engineer, Radio Division, General Electric Company
 (Waltham, Mass.)
 Earl Hunt, Chief Engineer, Radio Division, General Electric Company
 (Waltham, Mass.)
 Harry Moran, Chief Engineer, Radio Division, General Electric Company
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 RAY D. SMITH, President
 Radio & Television Institute, Chicago



RADIO and TELEVISION INSTITUTE HOME TRAINING

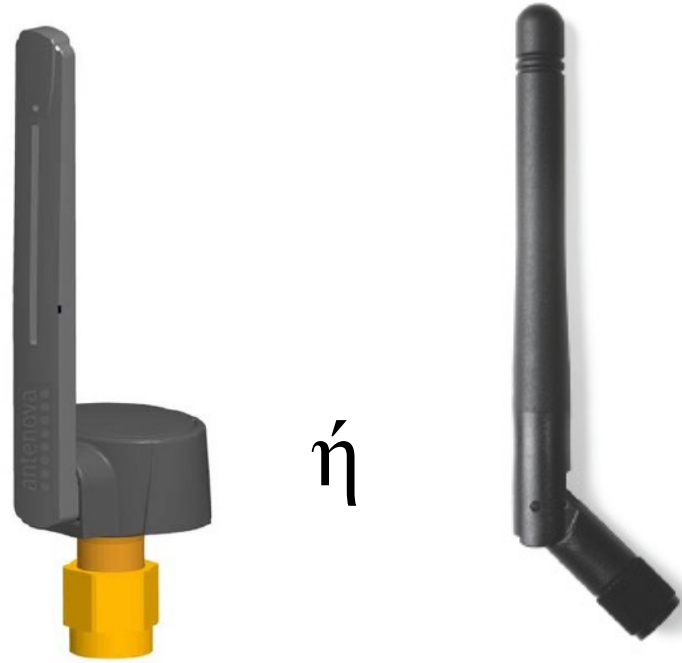
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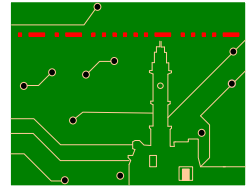
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RADIO and TELEVISION INSTITUTE, (R. T. I.)
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Κεραίες 2.4-2.5GHz



	Typical performance
Peak gain	2.2 dBi
Average gain	-1.0 dBi
Average efficiency	80%
Maximum Return Loss	-13 dB
Maximum VSWR	1.6:1



Frequency [GHz]	Gain [dBi]	Impedance [Nom]	VSWR	Polarization	Electrical Length	Radiation
2.4 – 2.5	2.0	50 Ω	≤ 2.0	Vertical	¼, dipole	Omni

Ερωτήσεις?

