Welcome to view the abstracts of articles that summarize my past and on-going researches. For your convenience, these abstracts are categorized as follows.

[1] Guidance properties of transmission lines embedded in layered medium
[2] Microstrip patch antennas
[3] Dielectric resonator antennas
[4] Coaxial antennas
[5] Miniaturized antennas and cavity-backed GPS antennas
[6] Propagation models and inverse problems in the atmosphere
[7] Scattering problems
[8] Evolutionary algorithms for phased-array optimization
[9] Radar signal processing
[10] Image reconstruction algorithms
[11] Low-frequency current sensing and microwave hyperthermia
[12] Electromagnetic shielding
[13] Integrated-circuit designs
[14] Wave-particle interactions
[15] Meta-material applications

Full contents of these articles can be viewed at the website:
http://cc.ee.ntu.edu.tw/~jfkiang/selected_publications.html

Citation of these articles in your works is deeply appreciated.

A brief review of progress in the past ten years:

Jean-Fu (Jeff) Kiang has been guiding his students to apply different ideas, theories and methods in exploration of various electromagnetic phenomena and possible applications. Recent endeavors include how to merge multiple modes in a dielectric resonator antenna to increase its bandwidth (2007- 2009); how a tsunami wave perturbs the ionosphere and affects the GPS signals, leading to a method to detect a tsunami within 15 minutes of occurrence (2009); how to design 3D miniaturized broadband antennas with size of $\lambda/10$ (2010, 2011); how to improve the accuracy of a differential GPS system to within a few cm at a distance of 100 km from the reference station, leading to one possible application to measure the real-time wind field within a typhoon (2011); how to optimize different phased arrays by using evolutionary algorithms (2013-2015); how to reconstruct a better image of a celestial object 60 million light-years from the Earth, based on very-long baseline interferometry (2014); how to design super-lenses with meta-materials to achieve a resolution of $\lambda/30$ (2014); how to simulate wave propagation in the lower atmosphere, considering the effects of refractivity profile inversion and turbulence, under different weather conditions (2014); how to model the synchronization among an array of coupled oscillators originally operating at different

frequencies (2014, 2015); how to reconstruct high-fidelity microwave images of multiple underground objects (2014, 2015); how to simulate wave scattering by a very large rough surface (2015); how to compensate for the coupling among antennas in an array to improve the direction-of-arrival estimation to within 0.1°, even from directions far away from normal incidence (2015); how to evaluate the impact on ground objects from a high-altitude electromagnetic pulse (2016); how to estimate the parameters of an evolving sand-and-dust storm using improved radar equations (2016); how to apply LEO-ground infrared laser occultation technique and a harmony search algorithm to retrieve major greenhouse gas profiles around a specific receiver site in nearly real time (2017); how to apply synthetic-aperture radar (SAR) imaging on ground objects at high squint angles (2017); how to compensate motion errors in SAR imaging (2017); how to apply microwave hyperthermia to treat cancers (2018, 2019); how to process radar signals to estimate direction-of-arrival (DOA) and carrier frequency of multiple signal sources with co-primed array and triply-primed array techniques (2018, 2019); how to compute the brightness temperatures from very lossy medium by using finite-difference time-domain (FDTD) method to obtain near-field bistatic transmission coefficients and by extending the Planck's law to lossy medium (2019).

Documents of these works and other interesting explorations can be viewed at the website:
http://cc.ee.ntu.edu.tw/~jfkiang/selected_publications.html

Citation of these articles in your works is deeply appreciated.

A complete publication list can be found at
http://www.ee.ntu.edu.tw/publist1?teacher_id=942004&p=3

[1] Guidance properties of transmission lines embedded in layered medium

J.-F. Kiang, S. M. Ali, and J. A. Kong, "Integral equation solution to the guidance and leakage properties of coupled dielectric strip waveguides," *IEEE Trans. Microwave Theory Tech.*, vol.38, pp.193-203, February 1990.

Abstract -The guidance and leakage properties of single and coupled dielectric strip waveguides are analyzed by using the dyadic Green's function and an integral equation formulation. Method of moments is applied to solve the integral equation for the dispersion relation. A method to predict the occurrence of leakage is proposed and confirmed by simulations. The attenuation constant can be computed accurately over a wide range of 60 dB.

J.-F. Kiang, S. M. Ali, and J. A. Kong, "Propagation properties of striplines periodically loaded with crossing strips," *IEEE Trans. Microwave Theory Tech.*, vol.37, pp.776-786, April 1989.

Abstract -A dyadic Green's function in the spectral domain is used to study the dispersion

characteristics of signal striplines in the presence of periodic crossing strips. A set of coupled vector integral equations in terms of the current distribution on the conductors is derived. Method of moments is then applied to compute the propagation constant. If the crossing strips have finite length, stop-band appears and is mainly affected by the period, the crossing-strip length, and the separation between the signal strip and the crossing strips. If the crossing strips have infinite length, traveling waves are induced on crossing strips, resulting in attenuation along the signal strip. The loss mechanism caused by leakage in a lossless medium is elaborated to better understand the signal integrity in electronic packages.

J.-F. Kiang, "Integral equation solution to the skin effect problem in conductor strips of finite thickness," *IEEE Trans. Microwave Theory Tech.*, vol.39, pp.452-460, March 1991.

Abstract -The skin effect of single and coupled conductor strips of finite thickness is analyzed by using the dyadic Green's function and an integral equation formulation. Method of moments is used to solve the integral equation for the dispersion characteristics. The current distribution within the conductor is well represented to account for the ohmic loss. The effects of geometrical and electrical parameters on the conductor loss are investigated, which impact the signal integrity of interconnects at high-frequency electronic packages.

J.-F. Kiang, "Propagation and coupling characteristics of microstrip lines with laminated ground plane," *IEEE Trans. Microwave Theory Tech.*, vol.44, pp.208-217, February 1996.

Abstract **-** The effect of laminated ground plane on the propagation and coupling characteristics of microstrip lines is analyzed. An integral equation in the spectral domain is formulated, and method of moments is applied to compute the phase and the attenuation constants of several microstrip line structures.

J.-F. Kiang, "Microstrip lines on substrates with segmented or continuous permittivity profiles," *IEEE Trans. Microwave Theory Tech.*, vol.45, pp.229-235, February 1997.

Abstract-The propagation properties of microstrip lines on a substrate with inhomogeneous permittivity and conductivity profiles are analyzed. The eigenmodes in each inhomogeneous layer are obtained numerically, which are used to derive a numerical Green's function. An integral equation is then derived in terms of the surface current on the strip. Method of moments is then applied to solve the integral equation for the propagation constant. This method can also be applied to study the effects of random permittivity deviation in the substrate.

J.-F. Kiang, "Capacitance of microstrip lines with inhomogeneous substrate," *IEEE Trans. Microwave Theory Tech.*, vol.44, pp.1703-1709, October 1996.

Abstract- A mode-matching technique is combined with an integral equation approach to compute the capacitance matrix of microstrip lines embedded in an inhomogeneous stratified medium. In each layer, eigenmodes are obtained numerically to represent the potential distribution. The interaction between eigenmodes in two adjacent layers is characterized with a reflection matrix. A numerical Green's function is thus obtained to represent the potential induced by a line charge. Integral equation is then formulated in terms of the charge distribution and the imposed voltage on the microstrip lines. Method of moments is then applied to solve the charge distribution and hence the capacitance matrix. This method can also be applied to study the effects of random permittivity deviation in the substrate.

J.-F. Kiang, "Quasi-TEM analysis of coplanar waveguides with an inhomogeneous semiconductor substrate," *IEEE Trans. Microwave Theory Tech.*, vol.44, pp.1586-1589, September 1996.

Abstract- Phase and attenuation constants of coplanar waveguides, with finite metal thickness and lossy inhomogeneous insulator-semiconductor substrate, are computed and analyzed. Electroquasistatic approximation is adopted to derive a Laplace's equation with a complex permittivity in each inhomogeneous layer. The potential in each layer is represented by a Fourier sine series, and a reflection matrix characterizing properties between adjacent layers is derived to facilitate the computation. The potential on the center metal strip is represented in terms of its surface charge distribution, which is obtained by solving the integral equation with method of moments. The guidance properties of signal lines on semiconductor substrate, as in silicon-based integrated circuits, can be analyzed with this method.

Summary-

In stratified media with homogeneous layers, integral equations in the spectral domain are derived in terms of the dyadic Green's function in the media and the unknown sources of fields. These sources can be surface current on microstrip lines of zero thickness, equivalent volume current in dielectric strips and microstrip lines of finite thickness. Method of moments is applied to solve the integral equations for the dispersion relation of the transmission-line structures. The attenuation constant of coupled dielectric strips are computed accurately over a wide range of 60 dB. The attenuation of microstrip lines, attributed to leakage along crossing strips, is accurately computed. The attenuation due to skin-effect in microstrip lines of finite thickness is also accurately computed. These three papers elaborate three different important transmission lines based on rigorous formulation, and the numerical results are well explained with relevant physical mechanisms.

A laminated composite medium is modeled as a cascade of anisotropic homogeneous layers, with the fields in adjacent layers characterized by a transition matrix. The Green's function in the integral equation is represented as a product of transition matrices associated with multiple layers from the source position to the transmission line on which the boundary condition is imposed. Transmission lines or resonators embedded in composite materials like epoxy resin embedding

graphite fibers, commonly used in vehicles and airplanes, can be studied with this method.

In stratified media with inhomogeneous layers (for example, layers with segmented permittivity, semiconductor, random permittivity deviation), the Green's function in closed form is not available. Instead, a numerical Green's function is derived. Firstly, mode-matching technique is applied to represent the fields in each layer. By imposing the continuity conditions between adjacent layers, the numerical Green's function between current sources and fields, or charge source and potential, is obtained. Reflection matrices are defined at interfaces between adjacent layers to facilitate the computation. An integral equation between sources and fields (potential) on conductor surface is formed and then solved by using method of moments. These works help understand the guidance properties and the key parameters of transmission lines in electronic packages or semiconductor substrate, which become more important for signal integrity when the operating frequency increases and the package size decreases.

[2] Microstrip patch antennas

S. M. Ali, T. M. Habashy, J.-F. Kiang, and J. A. Kong, "Resonance in cylindrical-rectangular and wraparound microstrip structures," *IEEE Trans. Microwave Theory Tech.*, vol.37, pp.1773-1783, November 1989.

Abstract – A rigorous analysis on the resonance frequency of both the cylindrical-rectangular and the wraparound microstrip structure is presented. The problem is formulated in terms of a set of vector integral equations. Using Galerkin's method to solve the integral equations, the complex resonance frequencies are studied with sinusoidal basis functions which incorporate the edge singularity. Furthermore, the complex resonance frequencies are computed using a perturbation approach. Modes suitable for resonator or antenna applications are investigated.

J.-F. Kiang, "Rectangular patch resonator with laminated ground plane," *IEEE Trans. Antennas Propagat.*, vol.43, pp.1361-1368, December 1995.

Abstract - The effect of a laminated ground plane on the resonance frequency of rectangular patch resonators is analyzed. Each lamina of the ground plane is modeled as an anisotropic layer and a transition matrix is derived to relate the tangential field components in adjacent laminas. An integral equation in the spectral domain is formulated, which is solved by applying method of moments to compute the resonance frequencies.

J.-F. Kiang, "Resonance properties of cylindrical-rectangular patch with composite ground plane," *IEE Proc. Microwave Antennas Propagat.*, vol.142, no.4, pp.307-313, August 1995.

Abstract - Resonance characteristics of cylindrical-rectangular patch resonator in the presence of a laminated ground plane are studied. The laminated ground is modelled by a cascaded transition

matrix in the spectral domain. An integral equation is formulated in terms of the surface current on the patch. Galerkin's method is then applied to solve for the resonance frequency. Factors analyzed include substrate thickness, substrate dielectric constant, and laminate conductivity. It is found that certain laminate conductivities cause more power loss than the others. Replacing a perfect conductor ground by a laminated composite may shift the resonance frequency by 10%.

J.-F. Kiang, "Propagation and coupling characteristics of microstrip lines with laminated ground plane," *IEEE Trans. Microwave Theory Tech.*, vol.44, pp.208-217, February 1996.

Abstract **-** The effect of laminated ground plane on the propagation and coupling characteristics of microstrip lines is analyzed. Each lamina is modeled as an anisotropic layer, and transition matrix is used to relate the tangential field components in different laminae. An integral equation is formulated in the spectral domain, and the Galerkin's method is applied to solve the integral equation for the phase and the attenuation constants of several microstrip-line structures. The effects of substrate dielectric are also studied. The attenuation constant variation thus obtained will be useful in circuit board design and in studying signal transmission in lamina environment.

J.-F. Kiang, "Radiation characteristics of rectangular patch antennas with a laminated ground plane," *IEE Proc. Microwave Antennas Propagat.*, vol.143, no.2, pp.107-112, April 1996.

Abstract **-** In modern aeronautical and automobile industries, composite materials are becoming increasingly popular for building the vehicular surface. The antenna engineer may face the situation of needing to design patch radiators above the composite material instead of a conductor ground plane. The input impedance and radiation patterns of a rectangular patch antenna attached to a laminated ground plane by using an integral equation approach is studied herein. The effects of composite lamina, substrate thickness and current probe location on the input impedance and radiation patterns are analyzed. It is observed that the bandwidth of the patch antenna can be increased significantly when the substrate thickness is reduced. This observation can be used to design wideband microstrip antennas.

J.-F. Kiang, "Axisymmetric modes of cylindrical resonators with cascaded inhomogeneous dielectrics," *IEEE Trans. Microwave Theory Tech.*, vol.44, pp.1606-1610, September 1996.

Abstract **-** A generic numerical scheme is developed to calculate the resonant frequency of axisymmetric modes in an inhomogeneous cylindrical dielectric resonator. The resonator consists of sections of cylindrically stratified dielectrics within a cylindrical waveguide. In each section, the TM_{0m} and TE_{0m} waveguide modes are solved by expanding the H_φ and E_φ components in terms of the eigenmodes in an empty waveguide. The fields in each section are then expanded in terms of these TM_{0m} and TE_{0m} modes. The transverse resonance technique is then applied to compute the resonant frequencies. Comparison with literatures validates the efficacy of this approach. Results

with continuous dielectric profiles are also presented.

J.-F. Kiang, "Wraparound patch resonators on a composite ground plane," *IEE Proc. Microwave Antennas Propagat.,* vol.144, no.5, pp.301-304, October 1997.

Abstract **-** The effects of a laminated ground plane on the resonant frequencies of wraparound patch resonators are studied. An integral equation is formulated in terms of the surface current on the patch. The laminated ground is modelled by a transition matrix in the spectral domain, including the factors of substrate thickness, substrate dielectric constant and laminate conductivity. It is found that more power loss occurs with certain laminate conductivities.

[3] Dielectric resonator antennas

T.-H. Chang and J.-F. Kiang, "Dual-band split dielectric resonator antenna," *IEEE Trans. Antennas Propagat.,* vol.55, no.5, pp.3155-3162, Nov. 2007.

Abstract- A dual-band dielectric resonator antenna (DRA) is designed by splitting a rectilinear dielectric resonator (DR) and carving notches off the DR. It is observed that notches carved at different spots affect different modes. Removal of dielectric material from a spot with strong electric field significantly increases the resonant frequency. An abrupt change of normal electric field across the DR-air interface reduces the Q factor and hence increases the impedance bandwidth. Both TE111 and TE113 modes are merged to obtain a broadside radiation pattern on the horizontal plane. The proposed DRA covers both WiMAX (3.4-3.7 GHz) and WLAN (5.15-5.35 GHz) bands.

T.-H. Chang and J.-F. Kiang, "Broadband dielectric resonator antenna with metal coating," *IEEE Trans. Antennas Propagat.,* vol.55, no.5, pp.1254-1259, May 2007.

Abstract-A broadband dielectric resonator (DR) antenna is designed by coating copper on three vertical facets of a rectilinear DR and placing it on a horizontal ground plane. The DR-air interface is modeled as perfect magnetic conductor. A coplanar waveguide with terminating slots is used to feed the antenna. A wide bandwidth of 47% is obtained, over which the pattern on the horizontal plane is nearly omnidirectional. The 10-dB impedance bandwidth of this DR monopole covers 4.2-6.8 GHz, making it suitable for WLAN 802.11a applications.

T.-H. Chang and J.-F. Kiang, "Broadband dielectric resonator antenna with an offset well," *IEEE Antennas Wireless Propagat. Lett* , vol.6, pp.564-567, 2007.

Abstract- A broadband dielectric resonator (DR) antenna embedding an offset well is proposed. The well perturbs the original field distribution in the DR block to increase the impedance bandwidth associated with TE111 mode. The feeding aperture generates a similar radiation pattern in adjacent

band, resulting in a 5-6 GHz band to cover WLAN 802.11a.

T.-H. Chang, Y.-C. Huang, W.-F. Su, and J.-F. Kiang, "Wideband dielectric resonator antenna with a tunnel," *IEEE Antennas Wireless Propagat. Lett.*, vol.7, pp.275-278, 2008.

Abstract- A wideband rectilinear dielectric resonator (DR) embedding a horizontal tunnel is proposed. The bandwidth of the TE111 mode is increased because the tunnel reduces the Q factor of the DR. As the tunnel position is elevated, the electric field distribution of the TE112 mode near the top surface of DR becomes similar to that of the TE111 mode, resulting in a broadside radiation pattern. The bands of both modes are merged to achieve a wide bandwidth of 20% (4.76-5.86 GHz), with broadside radiation pattern of vertical polarization on the horizontal plane, making it suitable for WLAN 802.11a applications.

T.-H. Chang and J.-F. Kiang, "Sectorial-beam dielectric resonator antenna for WiMAX with bent ground plane," *IEEE Trans. Antennas Propagat.*, vol.57, no.2, pp. 563-567, Feb. 2009.

Abstract- A dielectric resonator (DR) antenna embedding a well is designed, with its horizontal beamwidth increased to more than 120° by bending the ground plane, and its 10-dB impedance band covers 3.4-3.8 GHz. It can be used as a sectorial antenna in WiMAX base station.

T.-H. Chang and J.-F. Kiang, "Bandwidth broadening of dielectric resonator antenna by merging adjacent bands," *IEEE Trans. Antennas Propagat.*, vol.57, no.10, pp.3316-3320, Oct. 2009.

Abstract-A broadband dielectric resonator (DR) antenna is designed by merging three resonant bands associated with TE111 , TE112 and TE113 modes, respectively. An asymmetrical moat is carved off the DR, which perturbs the electric field distribution within the DR to reduce the Q factor, and the radiation pattern on the *E* plane is modified to increase the gain in the broadside direction. A wide impedance bandwidth of 33% (4.89-6.86 GHz) is obtained, with broadside radiation pattern of vertical polarization on the horizontal plane. This DR antenna can be used for WLAN 802.11a applications.

Summary-

By using high-permittivity dielectric resonator (DR) as radiator, the antenna size can be significantly reduced, but the bandwidth of impedance and radiation pattern is reduced, as compared to patch antennas. To increase the operational bandwidth, two or more resonant modes in adjacent bands can be excited simultaneously to merge their individual bands. Since the radiation patterns associated with different modes are different, the field distributions of these resonant modes need to be modified to make the resulting radiation pattern consistent in all the bands of interest. In these works, different geometrical modifications are considered to fulfill the aforementioned requirements, including carving notches off DR, drilling a vertical well or horizontal tunnel in DR, inserting a moat

between a DR block and the surrounding DR. The feeding slot line is also used to increase the bandwidth and to modify the radiation pattern. In one design, a tall DR works like a dielectric-rod antenna, and the metal coating on its three vertical facets introduces monopole-like properties. In all these designs, the field distributions of different DR modes are inspected and elaborated to achieve the desired radiation pattern. In one design, the ground plane is bent to make the radiation pattern cover a horizontal sector of 120°, as specified in the requirements of some base-station antennas. Most of these DR antennas were designed to work in the WLAN or WiMAX bands. The design methodology is well extendable to DR antennas in other bands, and these works serve as good examples to exercise the design methodology.

[4] Coaxial antennas

J.-F. Kiang, "Radiation properties of circumferential slots on a coaxial cable," *IEEE Trans. Microwave Theory Tech.*, vol.45, pp.102-107, January 1997.

Abstract- Both method of moments and mode-matching method are used to compute the fields inside a coaxial cable around a circumferential slot, from which a reflection coefficient of signal in the cable and the radiation from the slot are determined. The accumulated effect of multiple slots on signal reflection is studied by using Monte-Carlo simulations. This method is proposed to study the efficacy of deploying a coaxial cable with multiple slots to distribute signals inside a tunnel-like environment.

J.-F. Kiang, "Analysis of linear coaxial antennas," *IEEE Trans. Antennas Propagat.*, vol.46, pp.636-642, May 1998.

Abstract- A coaxial-colinear antenna and a slotted coaxial antenna are studied for being used as base-station antennas in wireless communication systems. The region around slot is characterized with field-mode theory, the slot voltages and input impedance are obtained by applying a transmission-line analysis in which the radiation effect is represented by a shunt admittance and a serial admittance, respectively. The current distribution driven by slot voltages is then computed by using method of moments. The radiation pattern and directivity are then derived from the current distribution and the reflection coefficient inside the coaxial cable. The effects of frequency, permittivity of coaxial filling and segment number are analyzed to optimize the antenna performance.

Summary-

These practical antennas were studied in the booming stage of wireless communication systems. The coaxial cable with multiple slots is deployed in environments like tunnel or mine to distribute signals to the users. The linear coaxial antennas are used in the base station, which are highly directional in the vertical plane and omnidirectional in the horizontal plane. These problems are solved in three stages. The properties of a slot are modeled in terms of the field distribution around

the slot. The guidance of signals inside the cable is modeled as a transmission line with lumped loads at slot positions. The radiation properties are derived from either the slot fields or the current distribution on the outer conductor. The practical yet complicated structure is modeled from different perspectives and the intermediate results are integrated to obtain the final results.

[5] Miniaturized antennas and cavity-backed GPS antennas

W.-T. Hsieh and J.-F. Kiang, "A small broadband folded-loop antenna with disk-loaded monopole," *IEEE Antennas Wireless Propagat. Lett.*, vol.9, pp.1248-1250, 2010.

Abstract- A small broadband folded-loop antenna with a disk-loaded monopole is designed and measured. Its size is $0.08\lambda \times 0.1\lambda \times 0.1\lambda$ at the center frequency of 1.5 GHz. The measured fractional bandwidth is 11.2%, with the voltage standing-wave ratio (VSWR) less than 2. It has an omnidirectional radiation pattern of vertical polarization in the horizontal plane.

W.-T. Hsieh and J.-F. Kiang, "Small broadband antenna composed of dual-meander folded loop and disk-loaded monopole," *IEEE Trans. Antennas Propagat.*, vol.59, no.5, pp.1716-1720, May 2011.

Abstract- A small broadband antenna composed of a dual-meander folded loop and a disk-loaded monopole is designed. Measurement results indicate a fractional bandwidth of 10.8%, with the voltage standing-wave ratio (VSWR) less than 2. The measured radiation efficiency exceeds 65% over the whole band. This antenna has an omnidirectional radiation pattern of vertical polarization in the horizontal plane. The ground plane size is also optimized to achieve the required radiation properties.

W.-T. Hsieh, T.-H. Chang, and J.-F. Kiang, "Dual-band circularly polarized cavity-backed annular slot antenna for GPS receiver," *IEEE Trans. Antennas Propagat.*, vol. 60, no.4, pp.2076-2080, April 2012.

Abstract- A circularly polarized cavity-backed annular slot antenna for GPS receiver is designed to operate in both the L1 and L2 GPS bands. The measured impedance bandwidths, with VSWR less than 2, are 3.7% (1.19-1.235 GHz) and 1.2% (1.565-1.585 GHz), respectively; the measured 3 dB axial-ratio (AR) bandwidths are 0.9% (1.220-1.231 GHz) and 0.6% (1.572-1.581 GHz), respectively. A cavity is designed to render a unidirectional radiation pattern.

T.-H. Chang and J.-F. Kiang, "Compact multi-band H-shaped slot antenna," *IEEE Trans. Antennas Propagat.*, vol. 61, no.8, pp.4345-4349, Aug. 2013.

Abstract- A compact triple-band H-shaped slot antenna fed by a microstrip line is proposed. Four resonant modes are excited, including a monopole mode, a slot mode and their higher-order modes, to cover GPS (1.575 GHz) and Wi-Fi (2.4-2.485 GHz and 5.15-5.85 GHz) bands, respectively. Sensitivity of the slot geometry on the resonant modes is also studied. The measured gains at these

four resonant frequencies are 0.2 dBi, 3.5 dBi, 2.37 dBi and 3.7 dBi, respectively; and the total efficiencies are－2.5 dB, －1.07 dB, －3.06 dB and －2.7 dB, respectively. The size of this slot antenna is 0.24λ×0.1λ, where λ is the free-space wavelength at 1.575 GHz. It can be conformally installed on notebook PCs and handheld devices.

Summary-

Two miniaturized 3D antennas are designed for wireless communication devices, which can be contained in a cube with edge length shorter than 0.1λ. It is difficult to reduce the size of a planar antenna to this extent while keeping a 10% fractional bandwidth, with omnidirectional radiation pattern of vertical polarization in the horizontal plane.

One cavity-backed slot antenna is designed to receive GPS signals in two bands, the other planar slot antenna is designed to operate in one GPS band and two Wi-Fi bands. The field distributions on the slots are illustrated to explain how they work. The analysis of different geometrical parameters on impedance bandwidths is well documented for the users.

[6] Propagation models and inverse problems in the atmosphere

C.-L. Mai and J.-F. Kiang, "Modeling of ionospheric perturbation by 2004 Sumatra tsunami," *Radio Sci.*, vol. 44, RS3011, doi:10.1029/2008RS004060, Jun. 2009.

Abstract-A complete model is integrated to analyze the electron density perturbation arisen by tsunami-induced atmospheric gravity waves (AGWs), including mechanisms of thermal conduction, viscosity, ion drag and photo-ionization. The electron density perturbation in the ionosphere arisen by the Sumatra tsunami on 26 December 2004 is simulated with this model and matches well with the data connected to a passing-over satellite. The delay time between the initiation of AGWs and the responded ionospheric perturbation is also accurately estimated.

C.-L. Mai and J.-F. Kiang, "Reconstruction of ionospheric perturbation induced by 2004 Sumatra tsunami using computerized tomography technique," *IEEE Trans. Geosci. Remote Sensing,* vol. 47, no. 10, pp.3303-3312, Oct. 2009.

Abstract- A computerized tomography technique is extended to reconstruct a 3D profile of electron density perturbation in the ionosphere based on the total electron content (TEC) data received with an envisioned network of GPS receivers. The 2004 Sumatra event is used to demonstrate this method. A plausible early-warning system is proposed, including a practical plan of deploying GPS receivers on ocean currents.

S.-C. Tsai and J.-F. Kiang, "Floating dropsondes with DGPS receiver for real-time typhoon monitoring," *IEEE Trans. Geosci. Remote Sensing,* vol. 49, no. 11, pp.4363-4373, Nov. 2011.

Abstract- Both a geometrical correction and a residual-error correction schemes are proposed to

improve the positioning accuracy of a three-frequency differential global positioning system (DGPS) to the order of centimeters, at a distance up to 120 km from the reference station. It takes only one second of GPS receiving signal, making the system nearly real time. An ad hoc network of weather balloons carrying DGPS receivers is proposed to monitor the progress of a typhoon in real time. An empirical typhoon model is adopted to simulate the operation of the DGPS receivers in typhoon Morakot and hurricane Katrina to demonstrate the feasibility of this monitoring scheme.

Y.-H. Chou and J.-F. Kiang, "Effect of turbulence on wave propagation in evaporation ducts above a rough sea surface," *Forum Electromag. Res. Methods Appl. Technol.* (*FERMAT*), vol.1, 2014.

Abstract- A proper set of models are carefully selected from the literatures to form a complete perspective in simulating the wave propagation in evaporation ducts, under a close-to-realistic environment. The split-step Fourier (SSF) propagation algorithm is applied to analyze the propagation properties in evaporation ducts above a rough sea surface, with turbulence in the ducts. The scattering effect of the rough sea-surface is modeled with an effective reflection coefficient, including the Miller-Brown correction factor for surface roughness. The turbulence effect is simulated with a two-dimensional Kolmogorov power spectrum of refractive index fluctuation, which is derived from its three-dimensional counterpart by using the Wiener-Khinchin theorem, including the anisotropic effect of the outer scales. The average M-profile, the outer scales of turbulence, and the structure constant of the refractive index are categorized under different atmospheric conditions. Simulation results are presented and discussed over all possible atmospheric conditions to better understand the effect of turbulence on the evaporation ducts.

Y.-H. Chou and J.-F. Kiang, "Ducting and turbulence effects on radio-wave propagation in an atmospheric boundary layer," *Prog. Electromag. Res. B*, vol.60, pp.301–315, 2014.

Abstract- A split-step Fourier (SSF) algorithm is applied to simulate the propagation of radio waves in an atmospheric duct. The refractive-index fluctuation in ducts is assumed to follow a two-dimensional Kolmogorov power spectrum, which is derived from its three-dimensional counterpart via the Wiener-Khinchin theorem. The measured profiles of temperature, humidity and wind speed in the Gulf area on 28 April 1996 are used to derive the average refractive index and the scaling parameters in order to estimate the outer scale and the structure constant of turbulence in the atmospheric boundary layer (ABL). Simulation results show significant turbulence effects above sea in daytime, under stable conditions, which are attributed to the presence of atmospheric ducts. Weak turbulence effects are observed over lands in daytime, under unstable conditions, in which the high surface temperature prevents the formation of ducts. Note that ducting effects occur about 50% of the time on large water bodies, and dominate the propagation of radar and communication signals over long distances.

M.-M. Chiou and J.-F. Kiang, "Retrieval of refractivity profile with ground-based radio occultation by using an improved harmony search algorithm," *Prog. Electromag. Res. M*, vol. 51, pp.19-31, 2016.

Abstract- A ground-based radio occultation (RO) technique is proposed to retrieve the local atmospheric refractivity profile at a higher sampling rate than conventional space-based RO techniques, making it more suitable for regional weather studies. A harmony search (HS) algorithm with ensemble consideration (HS-EC) on atmospheric physics is proposed to retrieve the refractivity profile more efficiently and accurately. The highest altitude of profile is extended to 95 km from 40 km adopted in preceding ground-based RO techniques, resulting in more accurate reconstruction profiles. Note that the refractivity profile affects workable communication distance over large water bodies and the accuracy of GPS positioning.

M.-M. Chiou and J.-F. Kiang, "Retrieval of major greenhouse gas profiles with LEO-ground infrared laser occultation (LGIO) technique," *Prog. Electromag. Res. B*, vol. 72, pp.149–168, 2017.

Abstract- A LEO-ground infrared laser occultation (LGIO) technique is proposed to retrieve local greenhouse gas (GHG) profiles, including the analysis of key factors and practical issues for effective operation. A harmony search with ensemble consideration (HS-EC) algorithm is applied to retrieve the volume mixing ratio (VMR) profiles of H2O and three major GHGs, CO2, CH4 and N2O. The vertical resolution of retrieved GHG profiles is 1 km from ground level up to 20 km above ground. The errors in VMR of H2O, CH4, N2O and CO2 are below 10, 5, 5 and 3%, respectively, up to 45 km above ground. Note that GHGs are the prime suspects to the global warming phenomenon.

M.-M. Chiou and J.-F. Kiang, "PWE-based radar equation to predict backscattering of millimeter-wave in a sand-and-dust storm," *IEEE Trans. Antennas Propagat.*, vol.65, no.2, pp.785-793, Feb. 2017.

Abstract- A radar equation based on parabolic wave equation (PWE) is proposed to compute the backscattered power of millimeter-wave in a sand and dust storm (SDS). The height profiles of particle size distribution and total number density are incorporated. The conventional radar equation is also improved by including the effects of Earth curvature and beam divergence. The improvement of accuracy by using these two radar equations, especially when the specific attenuation varies with height, is estimated by simulations. This method can be used to retrieve the spatial distribution of an SDS.

M.-M. Chiou and J.-F. Kiang, "Simulation of X-band signals in a sand and dust storm with parabolic wave equation method and two-ray model," *IEEE Antennas Wireless Propagat. Lett.*, vol.16, pp.238-241, 2017.

Abstract- A parabolic wave equation (PWE) method, including the effects of Rayleigh scattering and absorption by dust particles, is proposed to study the propagation of microwave signals in a sand and dust storm (SDS). A 3D SDS model is adopted in the simulations. The effects of Earth curvature and ground reflection are also incorporated. A time record of microwave attenuation is also simulated

and compared to the measurement data to demonstrate the efficacy of the proposed method.

M.-M. Chiou and J.-F. Kiang, "Attenuation of millimeter-wave in a sand and dust storm," *IEEE Geosci. Remote Sensing Lett.*, vol.13, no.8, pp.1094–1098, Aug. 2016.

Abstract- The attenuation of millimeter-wave signals in a sand and dust storm (SDS) is used to retrieve the SDS parameters. A parabolic wave equation (PWE) method is proposed to simulate the propagation of millimeter-wave in an SDS, including the effects of absorption and Rayleigh scattering by dust particles, as well as height profiles of particle-size distribution and total number density. Three different aperture fields of the transmitting antenna are also simulated to find the usable range of operational parameters.

J.-F. Kiang and S. H. Lin, "Propagation analysis of signal fading for Basic Exchange Radios," *IEEE Trans. Antennas Propagat.*, vol.41, pp.863-870, July 1993.

Abstract- Advances in microelectronics, digital radio, and voice coding technologies make basic exchange radio (BEXR) systems economically attractive for rural telecommunications services. The performance and reliability of a BEXR can be affected by multipath fading. Although empirical multipath fading models are available for microwave links above 2 GHz, these models are not directly applicable to the BEXR links because of the substantial differences in frequency, antenna beamwidth and radio-path clearance. In this paper, we present a method to obtain a scaling factor which accounts for the differences between BEXR and microwave links. First, we study the terrain scattering by using a rough surface model and the atmospheric refraction by using a ray tracing approach. Then, we calculate the received signal powers of a microwave link and two BEXR links on the same path under the same propagation condition. The signal characteristics are investigated and used to simulate the fading distributions for all three links. From the simulation results, we derive a scaling factor to modify the existing microwave multipath fading models for BEXR application. The predictions by the modified model agree well with measured BEXR data. This study shows that probability distribution of signal fading on BEXR links is a strong function of antenna height and beamwidth.

Summary-

As extreme weather events occurred more frequently in recent years, more concern about global warming and climate change are invoked among communities and authorities. Remote sensing technologies can play an important role in monitoring relevant phenomena and events. New requirements and challenges create opportunities for further improvement and integration of relevant technologies. We have been working on relevant subjects for many years. For example, a complete set of equations are integrated to describe how the tsunami-induced atmospheric gravity waves (AGWs) perturb the electron density in the ionosphere. The integrated model is applied to reconstruct the electron density profile during the Sumatra tsunami on 26 December 2004, and the

simulation results match well with the data connected to a pass-over satellite. A computerized tomography technique is extended to reconstruct a 3D profile of electron density perturbation in the ionosphere, based on the simulated total electron content (TEC) data received with an envisioned network of GPS receivers. A plausible early-warning system is proposed for the detection of a tsunami about 15 minutes after its onset.

A near real-time DGPS technology is proposed to demonstrate the feasibility of using floating GPS receivers for monitoring on-going weather events. An ad hoc network of floating DGPS receivers is also simulated to monitor the wind field of an on-going hurricane in real time.

Ducting and turbulence effects on radio-wave propagation (for radar and maritime communication), characterized by the atmospheric refractivity profile in the atmospheric boundary layer (from ground to 1 km above), are studied by using a split-step Fourier (SSF) algorithm. A ground-based radio occultation (RO) technique is proposed to retrieve the local atmospheric refractivity profile at a higher sampling rate than conventional space-based RO techniques, and the highest altitude of profile is extended to 95 km above ground, making it more suitable for regional weather studies. A LEO-ground infrared laser occultation (LGIO) technique is proposed to retrieve the local volume mixing ratio (VMR) profiles of greenhouse gases (GHGs), including H2O and three major GHGs, CO2, CH4 and N2O. The vertical resolution of the retrieved GHG profiles is improved. This method facilitates local monitoring of GHGs and can be extended to monitor local pollutants in real time.

A parabolic wave equation (PWE) method, incorporating the effects of Rayleigh scattering, Earth curvature, beam divergence and absorption by dust particles, is proposed to study the propagation of microwave and millimeter-wave signals in a sand and dust storm (SDS). The conventional radar equation is also improved to be capable of estimating SDS profiles with better spatial and temporal resolutions.

[7] Scattering problems

J.-F. Kiang, "Scattering by grooves of arbitrary profile on cylindrical surfaces," *Radio Science*, vol.32, no.5, pp.1777-1784, September-October 1997.

Abstract- A generalized mode-matching method is developed to study the scattering properties of conducting cylinders with periodic grooves of arbitrary cross section. Reflection matrices are derived to reduce the number of unknowns. This method is illustrated by studying three types of periodic groove with dielectric filling on a cylindrical surface. Radar cross-sections by an incident TE wave are obtained, and the effects of frequency, groove profile, groove depth, and filling permittivity are analyzed.

J.-F. Kiang, "Backscattering of TE waves by periodical surface with dielectric cover," *IEEE Trans. Antennas Propagat*., vol.46, pp.176-180, February 1998.

Abstract- Several types of periodical surface are studied on their backscattering to a normally incident TE plane wave. The surfaces are perfect conductor and are covered with dielectric materials to make a flat surface due to aerodynamic consideration. The effects of frequency, surface profile shape, period-to-depth ratio, and cover permittivity are analyzed. It is observed that a saw-tooth profile can be used to reduce the backscattering at high frequencies and elliptical profiles can be used to reduce the backscattering at certain low frequencies when cover material is filled in the grooves.

Z.-H. Lai, J.-F. Kiang, and R. Mittra, "A domain decomposition finite difference time domain (FDTD) method for scattering problem from very large rough surfaces," *IEEE Trans. Antennas Propagat.*, vol.63, no.10, pp.4468-4476, Oct. 2015.

Abstract- A domain-decomposition finite-difference time-domain (DD-FDTD) method is proposed to compute the scattering field from very large rough surfaces. The entire computational domain is decomposed into multiple sub-domains. Conventional FDTD method is applied to each sub-domain to compute the scattered fields on a Huygens' surface and the total fields on the rough surface. The latter is then used to compute the scattered field on the Huygens' surface in the other sub-domains, by invoking the reciprocity theorem. This method can be applied to simulate scattering fields and other derived parameters from very large rough surface in active or passive remote-sensing practices.

Z.-H. Lai and J.-F. Kiang, "Brightness temperatures from very lossy medium with near-field bistatic transmission coefficients," *IEEE Trans. Geosci. Remote Sensing,* accepted.

Abstract- The scattering fields from very lossy medium with a flat interface are computed by using a finite-difference time-domain (FDTD) method. Near-field bistatic transmission coefficients (BTCs) are proposed, and the Planck's law is extended to nondispersive lossy medium to compute the brightness temperatures from the lossy medium. The reciprocity relation on BTCs is utilized to reduce the computational load. The efficacy of the proposed method is verified by comparing the simulation results with the literature.

Z.-H. Lai and J.-F. Kiang, "Brightness temperatures from layered lossy medium with rough surfaces by combining FDTD and coherent methods," *IEEE Geosci. Remote Sensing Lett.*, accepted.

Abstract- The brightness temperatures from layered lossy medium with rough surfaces, where the physical temperature varies with depth, are computed by using the coherent method, with the field distribution computed by using the finite difference time domain (FDTD) method. The major contribution of the proposed method lies in its flexibility to compute the brightness temperatures from a layered medium with rough interfaces and spatially varying physical temperature. The brightness temperatures from a half-space lossy medium are validated by comparing with data in the literature, and the maximum error of the simulation results, as compared with literature, is 4.7 K (1.6 %), which is slightly above the threshold of 1 %.

[8] Evolutionary algorithms for phased-array optimization

S.-H. Yang and J.-F. Kiang, "Adjustment of beamwidth and side-lobe level of large phased-arrays using particle swarm optimization technique," *IEEE Trans. Antennas Propagat.,* vol. 62, no.1, pp.138-144, Jan. 2014.

Abstract-A particle swarm optimization (PSO) technique is applied to maintain a constant beamwidth of a large phased-array when its major lobe is steered away from the broadside direction. The first side-lobe is suppressed to a minimum possible level, at the expense of raising the other side-lobes. The excitation amplitude across the aperture is tapered to suppress the side-lobe level.

S.-H. Yang and J.-F. Kiang, "Optimization of asymmetrical difference pattern with memetic algorithm," *IEEE Trans. Antennas Propagat.,* vol. 62, no.4, pp.2297-2302, Apr. 2014.

Abstract- A memetic particle swarm optimization (MPSO) algorithm is applied to fine-tune the asymmetrical difference pattern of a linear array, which is useful for tracking targets in radar applications. At specified peak difference, the side-lobe level of the asymmetrical difference pattern can be successfully reduced while maintaining the desired squint angle and the side-lobe difference. The performance of optimization is compared with conventional PSO, genetic algorithm (GA) and memetic GA (MGA), with uniformly-excited array and Bayliss linear array, respectively, as the initial condition.

S.-H. Yang and J.-F. Kiang, "Optimization of sparse linear arrays using harmony search algorithms," *IEEE Trans. Antennas Propagat.*, vol.63, no.11, pp.4732-4738, Nov. 2015.

Abstract- A sparse linear array, composed of a uniformly spaced core sub-array and an extended sparse sub-array, is synthesized with a harmony search (HS) and an exploratory harmony search (EHS) algorithms. The optimal solution is searched by changing the amplitudes of all the elements and the positions of the extended elements, under a set of practical constraints. Performances of EHS, HS, a genetic algorithm (GA) and a particle swarm optimization (PSO) algorithm are also compared in synthesizing these sparse linear arrays.

S.-H. Yang and J.-F. Kiang, "Two-dimensional pattern synthesis of stacked concentric circular antenna arrays using bee colony algorithms," *Prog. Electromag. Res. B,* vol.55, pp.151-168, Sept. 2013.

Abstract- Stacked concentric circular antenna arrays (SCCAAs), which can operate in both scanning mode and tracking mode, are optimized in both the azimuth and elevation planes. A gbest-guided artificial bee colony algorithm (GABCA) is adopted to optimize the dual-mode field patterns of thinned SCCAAs. The performance is compared with that of conventional ABCA and particle swarm optimization (PSO) algorithms.

Summary-

Different phased-array configurations, for different radar applications, are synthesized by using various evolutionary algorithms (EAs), including PSO, MPSO, GA, MGA, HS, EHS, ABCA and GABCA. The performances of other applicable EAs are also compared to better understand the advantages and disadvantages of these EAs in synthesizing different phased arrays.

[9] Radar signal processing

P.-J. Tu and J.-F. Kiang, "Estimation on location, velocity and acceleration with high precision for collision avoidance," *IEEE Trans. Intell. Transport. Syst.*, vol. 11, no.2, pp.374-379, June 2010.

Abstract- An approach is proposed to estimate the location, velocity and acceleration of a target vehicle to avoid possible collision. Radial distance, velocity and acceleration are extracted from the hybrid linear-frequency modulation (LFM)/frequency shift keying (FSK) echoed signals and then processed with a Kalman filter and a trilateration process. This approach proves to converge fast with good accuracy. Two other approaches, an extended Kalman filter (EKF) and a two-stage Kalman filter (TSKF), are used as benchmarks for comparison. Several scenarios of vehicle movement are also presented to demonstrate the efficacy of this approach.

K.-H. Chen and J.-F. Kiang, "Coupling characterization of a linear dipole array to improve direction-of-arrival estimation," *IEEE Trans. Antennas Propagat.*, vol.63, no.11, pp.5056-5062, Nov. 2015.

Abstract- The reciprocity theorem is applied to account for the electromagnetic coupling among antennas in a linear dipole array, in the presence of multiple incident plane waves. By utilizing the direction-dependent coupling information, the direction-of-arrivals of the incident waves can be estimated more accurately by using the conventional ESPRIT (estimation of signal parameter via rotational invariance technique). Different coupling compensation methods in the literatures are compared to validate this method, and multiple incident waves of both uncorrelated and coherent nature are also simulated.

K.-H. Chen and J.-F. Kiang, "Effect of mutual coupling on the channel capacity of MIMO systems," *IEEE Trans. Veh. Technol.*, vol.65, no.1, pp.398-403, Jan. 2016.

Abstract- The reciprocity theorem is applied to derive an exact expression to remove the coupling effects embedded in the receiving voltages of an antenna array. The correlation coefficients of the multiple-input-multiple-output (MIMO) channel established with the antenna array is also modified to incorporate the direction-dependent coupling effects more accurately. The effects of mutual coupling on the channel capacity of MIMO systems in a line-of-sight (LOS), as well as a multipath environments, under different coupling assumptions, are simulated and compared.

P.-C. Chen and J.-F. Kiang, "An improved range-Doppler algorithm for SAR imaging at high squint

angles," *Prog. Electromag. Res. M*, vol. 53, pp.41-52, 2017.

Abstract- An improved range-Doppler algorithm (RDA) is proposed to reconstruct images from synthetic aperture radar (SAR) data received at high squint angles. At a higher squint angle, a larger synthetic aperture is required to receive sufficient amount of data for image reconstruction, and the range migration also becomes more serious, which demands more computational load and larger memory size. The proposed method can generate better SAR images with less computational load and memory than the conventional RDA, which is verified by simulations.

P.-C. Chen and J.-F. Kiang, "SAR imaging on HEO satellites with an improved frequency-domain algorithm," *Prog. Electromag. Res. M*, vol.55, pp.189-201, 2017.

Abstract- The possibility of employing highly-elliptical-orbit (HEO) satellites for SAR imaging is investigated. A constellation of two satellites in the Tundra orbits, which are capable of covering high-latitude areas, are chosen as the platforms for SAR imaging. The received signal is processed with an improved frequency-domain algorithm (FDA) to reconstruct the image. Simulation results verify that the proposed method can produce better SAR images with less computational load and memory than the conventional FDA.

P.-C. Chen and J.-F. Kiang, " Data-driven strategies for cross-track motion compensation in synthetic aperture radar imaging," *Prog. Electromag. Res. B*, vol.76, pp.59-71, 2017.

Abstract- Nine different strategies are proposed to compensate the cross-track motion errors in synthetic aperture radar (SAR) imaging, based on estimating the phase coefficients of the phase history. A spline interpolation method and a subaperture reconstruction method are used to derive the phase history over the whole aperture, based on the phase coefficients previously estimated. Four different scenarios are designed to compare the performance of these nine strategies.

P.-C. Chen and J.-F. Kiang, "Improved chirp scaling algorithms for SAR imaging under high squint angle," *IET Radar Sonar Navig.*, vol.11, pp.1629-1636, Nov. 2017.

Abstract- Four improved chirp scaling algorithms (CSAs) are proposed to reconstruct images from synthetic aperture radar (SAR) data received at high squint angles, in which a larger synthetic aperture is required to receive sufficient amount of data for image reconstruction, and the range migration also becomes more serious, demanding more computational load and larger memory size. The proposed methods reconstruct better SAR images with less computational load and memory than the conventional CSA, which are verified by simulations.

K.-C. Hsu and J.-F. Kiang, "DOA estimation of quasi-stationary signals using a partly-calibrated uniform linear array with fewer sensors than sources," *Prog. Electromag. Res. M*, vol.63, pp.185-193, 2018.

Abstract- A two-step method is proposed to estimate the direction-of-arrivals (DOAs) of

quasistationary source signals, with a partly-calibrated uniform linear array (PC-ULA). The special structure of Toeplitz matrix is utilized to estimate the sensors' uncertainties. Then, a Khatri-Rao (KR) based multiple signal classification (MUSIC) algorithm is proposed to estimate the DOAs of source signals. Simulation results show that the proposed method renders lower root-mean-square-error (RMSE) than existing KR-based ESPRIT algorithms, especially under low signal-to-noise-ratio (SNR) and small angle separation between DOAs. It is also shown that the proposed method increases the degree-of-freedom (DOF) by one, as compared to its ESPRIT counterparts.

K.-S. Yang, P.-C. Chen and J.-F. Kiang, "Estimation of motion parameters with dual-frequency InSAR imaging technique," *Prog. Electromag. Res. C,* vol.81, pp.161-169, 2018.

Abstract- A dual-frequency InSAR imaging technique is proposed to estimate the position and motion parameters of a moving target, including velocity and cross-track acceleration. Conventional methods of estimating the velocity and acceleration of a moving target, from the phase information of bistatic SAR signal, are usually compromised by phase ambiguity. By applying the dual-frequency technique, phase ambiguity is effectively removed to ascertain accurate estimation of motion parameters. In addition, an alternative method is proposed to estimate different velocity components, by taking higher-order terms and solving coupled linear equations of the velocity components. The simulation results verify that the errors of velocity and acceleration are less than 1 m/s and 0.25 m/s^2, respectively.

K.-C. Hsu and J.-F. Kiang, "DOA estimation using triply primed arrays based on fourth-order statistics," *Prog. Electromag. Res. M*, vol.67, pp.55-64, 2018.

Abstract- A triply primed array (TPA) is configured on three mutually primed integers (N_1, N_2 and N_3), which operates with O($N_1N_2N_3$) degree-of-freedoms to estimate the direction-of-arrivals (DOAs) of multiple incident quasi-stationary signals. The set of unique and contiguous lags of the proposed TPA is searched and verified. Simulation results verify that the proposed TPA can detect more incident signals with higher accuracy than its compatible counterparts.

P.-C. Chen and J.-F. Kiang, "Review of modified algorithms for synthetic aperture radar imaging at high squint angles," *Forum Electromag. Res. Methods Appl. Technol.* (*FERMAT*), vol.26, Mar.-Apr. 2018.

Abstract- This paper summarizes the modified versions of chirp scaling algorithm (CSA), range-Doppler algorithm (RDA) and frequency-domain algorithm (FDA) for synthetic aperture radar (SAR) imaging at high squint angles. The reviewed methods can reconstruct better images with less computational load and memory than their conventional counterparts, which is verified by simulations. SAR imaging with highly-elliptical-orbit (HEO) satellites based on these techniques is also reviewed.

K.-C. Hsu and J.-F. Kiang, "Joint estimation of DOA and frequency of multiple sources with

orthogonal coprime arrays," *Sensors*, accepted.

Abstract- A two-stage method is proposed to jointly estimate the direction-of-arrival (DOA) and carrier frequency (CF) of multiple sources, by using two orthogonal coprime arrays (CPAs). The DOAs of CF-known sources are estimated first by applying a spatial-smoothing MUSIC algorithm. The contribution of these source signals is then removed from the originally received signal by applying an orthogonal complement projector. Next, a joint-ESPRIT algorithm is applied to estimate the DOAs and CFs of the remaining CF-unknown sources. With two orthogonal CPA(5, 6), the RMSE of DOA and CF of applying the proposed method to 30 sources, 13 of which having unknown CF, is less than 1 % at SNR > 5 dB.

[10] Image reconstruction algorithms

Y.-H. Kuo and J.-F. Kiang, "A recursive approach to improve the image quality in well-logging environments," *Prog. Electromag. Res. B*, vol.60, pp.287–300, 2014.

Abstract- A three-stage recursive approach is proposed to improve the recovered distribution of electric parameters in a well-logging environment. The first stage is executed by using the conventional linear sampling method (LSM) and the contrast source inversion (CSI) method. In the second stage, the background distribution is updated to better identify the target shape, using the recovered results in the first stage. In the third stage, the background distribution is made closer to the results in stage two, which improves the recovered distribution near the target boundary. The effect of noise is also simulated.

M.-M. Chiou, J.-F. Kiang, and R. Mittra, "A multi-feature visibility processing algorithm for radio interferometric imaging on next-generation telescopes," *Prog. Electromag. Res. C*, vol.52, pp.39-52, 2014.

Abstract- The visibility distribution is determined by the network configuration of observatories and can be categorized into different features, each covering different spectrum in the visibility plane. A computationally efficient multi-feature image reconstruction algorithm is proposed, which is more flexible to process massive amount of visibility data expected in the next-generation telescopes. In reconstructing an M87 image with the visibility data simulated on the Low-Frequency Array (LOFAR) configuration, this algorithm turns out to be a few hundred to one thousand times faster and is more resilient to noises than its predecessors.

Y.-H. Kuo and J.-F. Kiang, "An iterative approach to improve images of multiple targets and targets with layered or continuous profile," *Int. J. Microwave Science Technol*., article ID 376374, 2015, http://dx.doi.org/10.1155/2015/376374

Abstract- An iterative approach, based on the linear sampling method (LSM) and the contrast source inversion (CSI) method, is proposed to improve the recovered images of multiple targets and targets

with layered or continuous profile, including shape and distribution of electric properties. The difficulties in dealing with large targets or high contrast are partly overcome with this approach. Typical targets studied in the literatures are chosen for simulations and comparison.

M.-M. Chiou and J.-F. Kiang, "A visibility-domain reconstruction technique for optical interferometry imaging," *Prog. Electromag. Res. M*, vol. 53, pp.215-227, 2017.

Abstract- A visibility-domain processing for optical interferometric imaging (VP-OII) method is proposed to model the visibility distribution of an image, and a phase recovery technique is proposed to acquire additional visibility data from the power-spectrum and closure-phase data. This method requires only a few tunable parameters, and can be easily extended to include more data acquired from different instruments. In reconstructing an LkHα 101 image, the proposed method turns out to be a few hundred times faster and is more resilient to noise than the original multi-aperture image reconstruction algorithm (MIRA).

[11] Low-frequency current sensing and microwave hyperthermia

J.-F. Kiang, T. M. Habashy, and J. A. Kong, "Electrostatic fields due to an electrode mounted on a conducting pad of finite extent in a planar stratified medium," *IEEE Trans. Antennas Propagat.*, vol.37, pp.1140-1149, September 1989.

Abstract- The quasistatic fields generated by an electrode mounted on a perfectly conducting pad of finite extent and embedded in a planar stratified medium are analyzed. An integral equation in the spectral domain is derived for the outflowing current density distribution on the pad-electrode surface. The method of moments is then applied to solve the integral equation. The effects of the electric properties of the stratified medium and the standoff thickness on the total electrode current are investigated. Several conductivity profiles modeling different practical measurement environments are also considered.

C.-C. Chen and J.-F. Kiang, "Efficacy of magnetic and capacitive hyperthermia on hepatocellular carcinoma," *Prog. Electromag. Res. M*, vol.64, pp.181-192, 2018.

Abstract- The efficacy of applying magnetic hyperthermia (MHT) and capacitive hyperthermia (CHT) to treat hepatocellular carcinoma (HCC) is studied. Magnetoquasistatic (MQS) and electroquasistatic (EQS) formulations are developed to compute the magnetic field and electric field distributions, respectively, which are numerically solved by using finite element method. The heat transport equation is applied to compute the temperature distribution in the treated area. Simulation results of temperature distribution are used to compare the efficacy of MHT and CHT.

C.-C. Chen and J.-F. Kiang, "Electroquasistatic model of capacitive hyperthermia affected by heat convection," *Prog. Electromag. Res. C*, vol. 89, pp.61-74, 2019.

Abstract- An electroquasistatic (EQS) model of capacitive hyperthermia for treating lung tumors is proposed, based on which the finite element method is applied to compute the electrical potential in a human thorax model. The temperature distribution in the thorax model, which is surrounded by a bolus maintained at constant temperature, is computed by numerically solving a bio-heat equation, which includes metabolic heat generated in the tissues, heat convection mechanism in tissues and bolus, as well as the heat delivered by the microwave field computed with the EQS model and finite element method. Temperature-dependent blood perfusion rates of blood and muscle, respectively, are adopted to account for the physiological reaction of tissues to temperature variation. By simulations, it is observed that by adjusting the dielectric properties of adipose tissue via injection, the time evolution of temperature distribution can be controlled to some extent, providing more flexibility to customize a hyperthermia treatment plan for specific patient.

[12] Electromagnetic shielding

J.-F. Kiang, "On resonance and shielding of printed traces on a circuit board," *IEEE Trans. Electromagn. Compat.*, vol.32, no.4, pp.269-276, November 1990.

Abstract- *A* rigorous formulation in the spectral domain is used to investigate the radiation from unterminated traces printed on a circuit board in the frequency range from 30 MHz to 1 GHz. Both the effect of coupling among adjacent traces on the resonant frequencies, and the shielding effectiveness of metallic coating on the plastic cover are analyzed. It is found that the radiation around resonant frequencies is critical to comply with the FCC specifications, and an appropriate coating can resolve the problem.

J.-F. Kiang, "Shielding effectiveness of single and double plates with slits," *IEEE Trans. Electromagn. Compat.*, vol.39, no.3, pp.260-264, August 1997.

Abstract- Transverse-electric (TE) wave transmission through slits on single and double metal plates of finite thickness is studied by using the Galerkin's method. It is observed that by using either a thick plate (for slit narrower than half a wavelength) or double plates with slits laterally shifted (for slits wider than half a wavelength), the amount of power transmitted through the slits can be significantly reduced. These schemes can be applied to improve the shielding effectiveness of equipment cabinet.

J.-F. Kiang, "Wave penetration through slits on stacked thick plates," *IEEE Trans. Microwave Theory Tech.*, vol.46, pp.889-893, July 1998.

Abstract- Wave penetration through slits on single and stacked metal plates of finite thickness is studied by using the Galerkin's method. The limiting case of slits on infinitesimally thin plates are also formulated to compare the shielding effectiveness of slit metal plates against incident plane waves. It is observed that the wave penetrating through slits on stacked plates with a proper

separation is much less than that through a single slit on a plate with twice the thickness.

J.-F. Kiang and S.-H. Chen, "Wave penetration through bent slots," *IEEE Trans. Electromagn. Compat.*, vol.43, no.3, pp.390-394, August 2001.

Abstract- Shielding effectiveness of bent slots carved in a metal plate of finite thickness is analyzed by forming a set of integral equations based on the equivalence principle. Method of moments is used to solve the integral equations for the transmission cross-sections. The effects of slot geometry, filling permittivity and filling conductivity are studied. It is found that the penetrating field is mainly determined by the slot length, filling permittivity and filling conductivity. Resonances are also observed when the slot length is integer multiplies of half wavelength.

[13] Integrated-circuit designs

I-Y. Li and J.-F. Kiang, "Design constraints on FSC LCD," *IEEE Trans. Electron Dev.*, vol.55, no.2, pp.533-539, Feb. 2008.

Abstract- Design constraints on field-sequential color liquid crystal displays (LCDs) are proposed and compared with those of conventional color filter LCDs. Application of these constraints to the design of LCD screens is demonstrated.

C.-H. Chen and J.-F. Kiang, "Active and adaptive charging method on data lines for delay compensation," *IEEE J. Display Technol*., vol. 4, no. 2, pp. 198- 203, June 2008.

Abstract- Charging time is a critical constraint in the design of large-size or high-resolution liquid crystal display. A fast charging method is proposed to generate adaptive charging voltages by comparing the pixel values between previous and current frames. Data line segmentation is also proposed to charge different subpixels on the data line precisely, which is implemented by using operational amplifiers and resistor networks.

I-Y. Li and J.-F. Kiang, "Charge recycling method on pixel level," *IEEE J. Display Technol*., vol. 4, no. 2, pp. 211 - 217, June 2008.

Abstract- A new power-saving design using charge recycling technique on the pixel level is proposed. Design constraints are derived and design examples are demonstrated. Compared with conventional charging methods, this method consumes only half the power, the charging speed is faster and the aperture ratio is similar.

P.-Y. Deng and J.-F. Kiang, "A 5 GHz CMOS frequency synthesizer with an injection-locked frequency divider and differential switched-capacitors," *IEEE Trans. Circuits Syst. I*, vol.56, no.2, pp.320-326, Feb. 2009.

Abstract- A phase-locked loop (PLL)-based frequency synthesizer at 5 GHz is designed and fabricated in 0.18 μm CMOS technology. The power consumption of the synthesizer is significantly

reduced by using an injection-locked frequency divider (ILFD) as the first frequency divider in the PLL feedback loop. The synthesizer chip consumes 18 mW of power, of which only 3.93 mW is consumed by the voltage-controlled oscillator (VCO) and the ILFD at 1.8 V supply voltage. The VCO has the phase noise of 104 dBc/Hz at 1 MHz offset and an output tuning range of 740 MHz. The chip size is 1.1 mm x 0.95 mm.

C.-E. Liu, Y-J. Hsieh, and J.-F. Kiang, "RFID regulator design insensitive to supply voltage ripple and temperature variation," *IEEE Trans. Circuits Syst.II*, vol. 57, no. 4, pp.255-259, April 2010.

Abstract- A regulator is designed for radio-frequency identification tags in the ultrahigh-frequency band using the TSMC 0.18 μm CMOS process. A stable reference voltage with short calibration time is designed by integrating a ripple stabilizer and a temperature stabilizer. The regulator output exhibits a line regulation and load regulation of 12 mV/V and 0.34 mV/mA, respectively, and its power supply rejection ratio is 35.1 dB at 1 MHz.

C.-H. Chang, Y.-T. Lo, and J.-F. Kiang, "A 30 GHz active quasi-circulator with current-reuse technique in 0.18 μm CMOS technology," *IEEE Microwave Wireless Comp. Lett.*, vol.20, no.12, pp.693-695, Dec. 2010.

Abstract- An active quasi-circulator at 30 GHz is designed and fabricated in TSMC 0.18 μm RF mixed-signal CMOS technology. The current-reuse technique is integrated with a common-source stage to form the quasi-circulator core while reducing the power consumption at the same time. The transmitter-to-receiver leakage is alleviated by the out-of-phase cancellation of signals from two paths. The isolation and insertion loss between other pairs of ports are improved with buffer stages. All the measured isolations are higher than 12 dB, all the insertion losses are lower than 7.9 dB, and the total power consumption is 15 mW.

Y.-T. Lo and J.-F. Kiang, "Design of wideband LNAs using parallel-to-series resonant matching network between common-gate and common-source stages," *IEEE Trans. Microwave Theory Tech*., vol.59, no.9, pp.2285-2294, Sept. 2011.

Abstract- A method is proposed to design wideband low-noise amplifiers (LNAs) made of cascaded common-gate (CG) and common-source (CS) stages with a parallel-to-series resonant inter-stage matching network. The first CG stage has a dual-band response and the second CS stage has higher gain between these two bands. By applying the proposed inter-stage matching technique, conjugate matching is achieved at high and low bands, while the mid-band loss is compensated by the second stage. The output network of the first stage and the input network of the second stage resonate at the same frequency. Two wideband LNAs are designed based on this method and implemented in 0.18 μm RF mixed-signal CMOS process. The first LNA operates at 3.1-10.3 GHz, having 9.6-12.71 dB of power gain and 2.5-3.9 dB of noise figure (NF) at the power consumption of 13.4 mW. The second LNA operates at 14.3-29.3 GHz, having 8.25±1.65 dB of power gain and 4.3-5.8 dB of NF at the power consumption of 13.9 mW.

Y.-T. Lo and J.-F. Kiang, "A 0.18 μm CMOS self-mixing frequency tripler," *IEEE Microwave Wireless Comp. Lett.*, vol.22, no.2, pp.79-81, Feb. 2012.

Abstract- A self-mixing frequency tripler with fundamental frequency between 6-7.3 GHz is built by cascading a doubler and a single-balanced mixer. The doubler and the mixer share a transconducting inductor to reduce the tripler core size when fabricated using the TSMC 0.18 μm RF mixed-signal 1P6M process. When the input signal frequency is 6.5 GHz at the power level of 3 dBm, the measured conversion gain is −9.5 dB, the HRR1 is 21.5 dBc, the HRR2 is 29 dBc, and the total dc power consumption is 18.8 mW.

Y.-T. Lo, C.-C. Yui and J.-F. Kiang, "OOK/BPSK-modulated impulse transmitters integrated with leakage cancelling circuit," *IEEE Trans. Microwave Theory Tech.*, vol.61, no.1, pp.218-224, Jan. 2013.

Abstract- A time-gating technique is adopted to design an on-off keying (OOK) and a binary phase-shift keying (BPSK) ultra-wideband impulse transmitters, respectively. A leakage-cancelling technique is proposed to suppress leakage signal from the oscillator, which is implemented by integrating a leakage-cancelling circuit with the output buffer of the OOK transmitter and the modulator of the BPSK transmitter, respectively. These two types of transmitter have been implemented using 0.18 μm RF CMOS technology. The measured leakage overshoot is less then 1.5 dBc in the OOK transmitter and is negligible in the BPSK version.

Y.-T. Lo and J.-F. Kiang, "Analysis on strongly coupled oscillator arrays using modified *Y*-parameters approach," *Prog. Electromag. Res. B*, vol.59, pp.71-87, 2014.

Abstract- A modified *Y*-parameters approach is proposed to model the behavior of coupled oscillator arrays (COA's). A coupling network with tunable coupling strength is proposed, which has near-constant input conductance, to ensure the oscillation condition under different attenuation levels. The parameters of oscillators and the coupling network are derived on the TSMC 0.18 μm technology and their *Y* parameters are extracted around 10 GHz for illustration. After being verified with full-circuit simulations and other behavior models, including the Adler's equation and the conventional *Y* -parameters approach, this method is applied to estimate the maximum allowable number of oscillators that can be coupled together. The inter-element phase shift of a COA is controlled by tuning the free-running frequencies of oscillators at both ends. Injection signals with proper phases are proposed to synchronize multiple COA's into a bigger COA.

Y.-T. Lo and J.-F. Kiang, "Comparison of injection-locked and coupled oscillator arrays for beamforming," *IEEE Trans. Microwave Theory Tech.*, vol.63, no.4, pp.1353-1360, Apr. 2015.

Abstract- Injection-locked oscillator arrays (ILOAs) and coupled oscillator arrays (COAs) are analyzed by using the Adler's equation, and their performance to drive phased arrays for

beam-steering is compared. The Monte-Carlo simulation results indicate that COAs render smaller beam-pointing error when the locking range of oscillators is narrow (high Q), while ILOAs render smaller beam-pointing error when the locking range is wide (low Q). An ILOA with a frequency tripler connected to the oscillators' output is designed to increase the achievable range of inter-element phase shift, and a chip is fabricated in the TSMC 0.18 μm CMOS technology to verify the design concept, with the measured maximum phase shift around 240°.

[14] Wave-particle interactions

H.-C. Wei and J.-F. Kiang, "Near-ground transient field of a high-altitude electromagnetic pulse (HEMP) considering nonlinear air conductivity and ground reflection," *Prog. Electromag. Res. M*, vol. 48, pp.45–54, 2016.

Abstract- Transient field of a high-altitude electromagnetic pulse (HEMP) induced near ground is simulated, of which the ground reflection cannot be neglected. The Jefimenko's equation is applied to compute the incident electric field near the ground, attributed to both the primary and the secondary currents in the source region. The field-dependent air conductivity in the source region is obtained by solving three nonlinear governing equations iteratively, and the reflected field is computed in the frequency domain.

H.-C. Wei and J.-F. Kiang, "Simulation of high-altitude electromagnetic pulse (HEMP) above sea surface," *Prog. Electromag. Res. M*, vol. 50, pp.195-204, 2016.

Abstract- High-altitude electromagnetic pulse (HEMP) radiated from both primary and secondary currents, which are induced by a nuclear explosion, is computed by using the Jefimenko's equation. The effects of geomagnetic field is considered in computing the primary current, and the rough sea surface is considered in computing the reflected electric field in the frequency domain. The waveforms of HEMP near sea surface and a few km above it are simulated. The impulse and pulse characteristics are discussed, as well as the variation of peak field magnitude when the observation point is moved away from beneath the burst point.

H.-M. Chang and J.-F. Kiang, "Transitional behaviors of CQGLE solitons across boundaries on a phase plane," *Prog. Electromag. Res. M*, vol. 55, pp.1-12, 2017.

Abstract- Soliton solutions of a cubic-quintic Ginzburg-Landau equation (CQGLE) are computed and analyzed on a parametric plane, specifically across the transitional zones that separate regions associated with different types of soliton. The transformations of behavior in these transitional zones between stationary and pulsating regions are characterized by the total pulse energy and its maximum value. It is also found that the initial pulse waveform has little effect on bifurcation and the valid range of initial amplitude.

[15] Meta-material applications

L.-H. Yeh and J.-F. Kiang, "Multilayered superlenses containing CsBr or active medium for subwavelength photolithography," *Prog. Electromag. Res. B,* vol.59, pp.1-18, Mar. 2014.

Abstract- The characteristics of periodic multilayered near-field superlenses are analyzed and optimized, using the dispersion relation derived from an effective medium theory and the transfer function in the spectral domain. The $k_z^{'}$ -k_x and $k_z^{''}$ -k_x contours are used to explain and predict the spectral width, amplitude and phase of the transfer function. Superlenses containing CsBr or active layers are proposed to reduce image distortion or to compensate for the propagation loss, respectively. The parameters of the superlenses can be optimized by simulations to resolve half-pitch features down to λ/36 using CsBr layers, and λ/20 using active layers.

Y.-H. Lin and J.-F. Kiang, "Efficiency improvement of *p-i-n* solar cell by embedding quantum dots," *Prog. Electromag. Res.*, vol.146, pp.167–180, 2014.

Abstract- A model of solar cell embedding quantum dots in the intrinsic layer of a *p-i-n* solar cell is presented. With proper selection of material, size and fractional volume, quantum dots can provide an intermediate band between the valence and the conduction bands of the matrix material, which will absorb photons with energy lower than the original bandgap, leading to absorption of more incident photons in the otherwise unused spectral irradiance. The design approach to acquire the highest efficiency of the conventional *p-i-n* solar cell is presented as a benchmark. Quantum dots are then embedded in the intrinsic region of the reference solar cell to improve its efficiency. InAs is chosen to implement the quantum dots, to be embedded in the *p-i-n* solar cell made of GaAs. With a more packed arrangement of QD's from that in the literatures, the simulation results show that the efficiency of the conventional GaAs *p-i-n* solar cell can be increased by 1.05 %.

L.-H. Yeh and J.-F. Kiang, "Microwave tunable metasurfaces implemented with ferroelectric materials and periodical copper wires," *Prog. Electromag. Res. M,* vol.37, pp.191-202, 2014.

Abstract- A tunable metasurface composed of multiple resonant units is proposed, with each unit containing a block of $SrTiO_3$ ferroelectric and a periodical copper-wire structure. The local transmission coefficient of the metasurface can be controlled by tuning the permittivity of $SrTiO_3$ via a bias voltage. A tunable metasurface is simulated to steer the beam direction at the angles of 30° and 14.47°, respectively. Another one is simulated to focus the wave beam at the focal lengths of $2\lambda_0$ and $4\lambda_0$, respectively.