

# Terahertz Pioneers

## *A Series of Interviews With Significant Contributors to Terahertz Science and Technology*

**A**S A TRIBUTE to individuals who have contributed significantly, and over many years, to the terahertz community, and as a guide and inspiration for those who are just beginning their professional association with this field of study, these transactions have included, on a regular basis, a series of biographical interviews with technical researchers who have appreciably impacted the THz community in a positive manner. In order to go beyond a strict technical review and to take better advantage of the information and commentary only available through a direct discussion, these articles take on a less formal style than the research articles that can be found within the remaining pages of the transactions. The Editor-in-Chief has taken some leeway in this regard, for the benefit of communicating more fully the character, experiences, and historic circumstances that have shaped our community and set the directions for our collective research. As a further means of assuring that the true flavor and circumstances of the contributions are expressed in the text, all of the articles are compiled after a face-to-face interview. The final text is shared with, and often helped considerably, by comments from the subject of the article. The Editor-in-Chief, with the support of the IEEE MTT Publications Committee, has chosen to incorporate these biographical articles within the more formal technical journal because of the diversity of disciplines that make up the THz community and the prior absence of a single unifying publication with sufficient outreach to extend across the whole of the RF and optical THz disciplines. The Editor-in-Chief hopes you will enjoy the short diversion of reading these articles as much as he himself enjoys the process of composing them.

This month I did not travel very far to reach our subject for the *THz Pioneer* article—just a modest drive across Los Angeles to the campus of UCLA. There I sat down with one of the most recognized names in all of electrical engineering, Professor Tatsuo Itoh<sup>1</sup>. Pick up almost any issue of IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES from 1970 onwards and you are almost sure to find at least one article by this prolific author of technical papers with more than 230 *Transactions* articles to date. Add to these another 200 journal articles, 860 refereed conference papers, 48 book

and book chapters, 76 Ph.D. students and 12,000 citations, and we have an influence that extends into almost every corner of microwave engineering—including into the THz regime.

However, Tatsuo Itoh's career path is not a simple meteoric trajectory to the top. After obtaining his Ph.D. from University of Illinois Urbana-Champaign in 1969, it would take another nine years, and significant personal sacrifice, before he found himself in a position that allowed him to flourish professionally and to realize his early ambitions.

I have met no one who can match Professor Itoh's work ethic, nor have I come across very many who are more willing to sacrifice their time and energy in support of their professional colleagues. These include not only his current and former students, who now number in the hundreds, but also his vast network of science and engineering associates, who have tapped Professor Itoh for everything from reviewing and references, to invited presentations and papers. But it does not stop here. Professor Itoh has served on several dozen boards and committees, he has been the Editor-in-Chief of two IEEE journals, he served as President of the Microwave Theory and Techniques Society and he has been a constant fixture at every MTTTS Administrative Committee meeting—3 per year—for over 25 years!

Where does he find the time? That is a question that this article cannot answer. Yet, those who know Professor Itoh, all vouch for his willingness to take on almost any professional task and to do so with 100% follow through on each and every commitment. Perhaps it is his approach to handling problems, as well as requests—speed and novelty. These are his self-avowed mantras for success. They seem to have worked very well!

One last note before we proceed. Although it is true that Professor Itoh's direct technical connections to THz are limited, like our November 2013 *THz Pioneer*, Sir John Pendry, it is the formative links that Professor Itoh forged that are important for the THz community. His focus on planar circuit and antenna analysis techniques led to many spin off designs that moved up the microwave frequency ladder. His stewardship of the IEEE MICROWAVE AND GUIDED WAVE LETTERS, which was originally envisioned as a journal that would help capture THz topics within the IEEE Microwave Theory and Techniques society, ultimately planted the seed that led to the establishment of this publication. Professor Itoh also attended and presented at almost every THz conference since the field began, and many of his students and associates have gone on to careers in our field. Finally, Professor Itoh's continuous support of expanded THz activities through his involvement in IEEE, led this author to conclude that his inclusion in this *Pioneer* series is indeed appropriate.

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<sup>1</sup>Tatsuo Itoh sat quietly with me in his office at the University of California, Los Angeles, USA, this past Valentine's Day, for this uninterrupted four-hour interview. As I pulled together his professional accomplishments, I was struck as much by his ability to tackle almost any problem in microwave engineering, as by his capacity and willingness to help any student or colleague who felt the need to call on his services. The sum total of Professor Itoh's contributions, both professional and technical, are so over the top; one feels more like he represents an entire department, rather than a single individual. This short article cannot hope to cover the breadth and influence of his full career, but at least it might give the reader a sense of how much can be accomplished in a single lifetime through unrelenting focus and sacrifice.

# Terahertz Pioneer: Tatsuo Itoh

## “Transmission Lines and Antennas: Left and Right”

Peter H. Siegel, *Fellow, IEEE*

**P**ROFESSOR TATSUO ITOH<sup>1</sup> acquired his professional work ethic at a young age. Waking up well before dawn to help with deliveries in his father’s milk business, spending the day in classes, the evening doing tutoring, and much of the time between twilight and dawn on his schoolwork, Itoh had little time for any self-indulgence. One of three boys growing up in the Yokosuka Naval district, south of Yokohama, Japan, immediately following World War II, Tatsuo remembers playing with handmade toys, especially wooden trains and paper objects he fashioned himself. His parents had graduated from teachers’ colleges and had been school teachers before the war, but his father had a difficult time getting steady work in the reconstruction years. They both had strong commitments to learning and they sent Tatsuo to a Jesuit high school with the best reputation for quality teaching in the district. Eiko Gakuen<sup>2</sup> still exists today and is ranked in the top 10 of 4000 high schools in Japan.

Tatsuo’s pre-college interests included history and gymnastics as well as math and physics. He also dabbled a bit in HAM radio, making vacuum tube receivers, and in optical astronomy. His life goal at the time was to attend Tokyo University. Getting in required passing a very tough entry exam, which he took twice, but failed both times. He blames his failure on a lack of mathematics skill—ironic considering his most important contributions to electronics were to be analytic and computational. He ended up in Yokohama National University, and perhaps fortuitously. Yokohama had no physics department, so Tatsuo

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<sup>2</sup>Established in 1947, Eiko Gakuen was housed in parts of the former Japanese Navy Base in Yokosuka. The school was established to fill Japan’s “spiritual vacuum” (<http://educationinjapan.wordpress.com/the-scoop-on-schools-a-survey-of-private-schools-in-japan-a-i/>). It was later moved to Kamakura and holds about 1000 boys for a six year pre-college program.



TATSUO ITOH

chose *Jakuden*<sup>3</sup> or “light electronics” which translates roughly into electronics and radio science—a field that would become his lifelong career.

Itoh specialized in radio electronics at Yokohama and recalls a lab project to design and build a vacuum tube power amplifier. Instead of the usual triode circuit, he used a pentode controlled by the current of the second grid, which he fed through the bias circuit. The novelty of the design earned him some notability within the department. As a consequence, his adviser, who had just returned from a visit to the U.S., selected Itoh to work on the newly invented ruby laser<sup>4</sup> as part of his senior thesis. Itoh built the system up from scratch, including the pulsed power supply. To his credit, when he finished his thesis in 1964, he had one of the first working lasers in Japan, and his university degree.

While completing his undergraduate work, Itoh was recruited by NEC’s Central Research Lab in Kawasaki, Kanagawa, Japan,

<sup>3</sup>Japanese electrical engineering coursework was either *Kyoden* “heavy” or *Jakuden* “light” electricity, the former involving power and plasmas, the latter electronics and radio.

<sup>4</sup>The pulsed ruby laser—the first operational laser—was demonstrated by Theodore Maiman in 1960 at Hughes Research Lab, Malibu, CA, USA: T. H. Maiman, “Stimulated optical radiation in ruby,” *Nature*, vol. 187, no. 4736, pp. 493–494, 1960.

where he had interned earlier characterizing phototransistors. However, instead of entering industry, he and a group of his college friends took an unusual path at the time, and they decided to all pursue advanced degrees. Yokohama had just instituted a Master's program so Itoh stayed in place, and again teamed up with his senior thesis advisor, K. Iijima [1], to work on lasers. This time he developed a composite resonator to optimize mode selection in a He-Ne laser (see, for example [2]), and then added tuning with an external mirror. During one of the summer periods, he interned at Olympus Camera where he picked up much of his exposure to commercial optics—a field which greatly influenced his later development work.

By the spring of 1966, his thesis project completed, Iijima suggested that Itoh continue his academic pursuits in America. Only one of the 20 odd universities he applied to in the U.S. was willing to accept this young Japanese student. It turned out to be University of Illinois, Urbana-Champaign. His acceptance at Illinois was due to Eikichi Yamashita, a post-doc of the renowned Raj Mittra,<sup>5</sup> and an early connection to THz [3] and transmission line analysis [4], who provided a very positive recommendation after reading Tatsuo's application.

Before leaving Japan, Itoh worked through the spring and summer teaching at Tamagawa University, Tokyo and earned enough money to cover his airfare to the U.S. He arrived in the fall of 1966 to what he described as a "rural desert" compared to the bustling environment of Tokyo. As a consequence, he settled into his studies with no cultural distractions. At Illinois, Itoh had a lot of course-work to catch up on, including math, physics and two additional languages (fortunately he was fairly fluent in English from the Jesuit school in Japan). He began his Ph.D. by working on the theory of confocal resonators under both Yamashita's and Mittra's supervision [5]. Taking up an idea from Illinois Professor Paul Coleman,<sup>6</sup> he also developed a technique for analyzing gratings with V-shaped grooves (echelette gratings [6]) using physical optics and scattering analysis. This was a time of intense work, with mid-morning coffee breaks at 10 PM not 10AM! However, Tatsuo did have time to meet his wife of now 45 years, Seiko, in an English class (she was a graduate student in sociology), and they were married in 1969, two days following the awarding of his Ph.D. degree [7].

After completing his dissertation, Itoh stayed on as a post-doc in Mittra's group for another 2 years before taking up a research appointment at Illinois. In this period he began focusing his efforts much more on transmission line analysis, which he had started during his thesis work. Between 1969 and 1976, Itoh and Mittra produced a prodigious amount of highly cited papers [8]–[29] and two book chapters [30], [31], covering strip gratings, striplines, microstrip, coupled microstrip, slot lines, dielectric guide, metal waveguides, optical waveguides, disks, periodic gratings, resonators and various flange and edge effects. Itoh also completed work on his most highly cited contribution

<sup>5</sup>Raj Mittra taught at Illinois from 1957 to 1996, and then moved to Penn State University where he is still active. Mittra is perhaps best known for his work on computational electromagnetics, but like Tatsuo Itoh, he is a prolific researcher and author with more than 700 papers and 35 books and book chapters covering a very wide variety of topics in electrical engineering.

<sup>6</sup>Coleman taught at Illinois from 1952 to 1988, and is well known to THz engineers for his work on harmonic generators and submillimeter-wave devices and techniques. He is an IEEE Centennial Medal winner from 1984.

to the microwave field, the extremely well utilized spectral domain approach for characterizing generalized transmission lines [27]–[32]. In this method, Itoh and Mittra formulate the field problem using the usual coupled integral equations approach, but then employ a Fourier transform to turn the integral solution into a series of simultaneous equations (expanded via a judicious choice of basis functions) that can be solved with matrix techniques. Eigenvalues are obtained for the propagation constants of the different modes. The approach is extremely general, and although it was first demonstrated on open microstrip lines [28], Itoh subsequently extended it to shielded lines [29] and later generalized transmission lines of all types [32].

At Illinois, Itoh also became very close with renowned antenna engineer Yuen Tze Lo<sup>7</sup> (Lo and Lee, *Antenna Handbook*) who was teaching electromagnetics. Professor Lo became a lifelong mentor and a companion, to whom Itoh could talk to about interests other than E&M, such as classical music and Chinese literature [33].

After several years as a research associate, Itoh was anxious to enter an academic track. However the 1970's saw the worst decline in academic employment in decades. Growth in faculty positions had slowed from 10.7% per annum in the 1960's to only 1.3% per annum by the mid 1970's [34]. Itoh saw many of his colleagues taking on extra work as taxi drivers! He applied to more than 50 institutions and despite his impressive publication record, received only one offer—at SRI (Stanford Research Institute) in Menlo Park, CA, USA. He moved there with his wife in 1976 and began work on C-band amplifiers for wireless microwave links. He quickly decided that the environment was not a good fit, and he again sent out applications for academic positions. University of Kentucky was the first place to respond positively, and Itoh left SRI in August 1977 for Lexington, KY, USA. Seiko, however remained in the San Francisco Bay Area.

At Kentucky, Itoh continued his prior analytic work and explored new directions [35]–[38]. He took up what would become an extended period as a cross-country family commuter. He was not really happy at Kentucky, however, as he found few colleagues and students he could comfortably team up with. In the meantime, his earlier application to University of Texas (UT), Austin had finally made its way through the department, and he was offered an Associate Professor slot in early 1978. He relocated to Austin in July, and there began a meteoric rise to the top of his profession.

Itoh's initial work at UT Austin was on millimeter-wave dielectric waveguide circuits [39]–[41], with support from the U.S. Army Research Office. He used a quasi-optical approach and tried to combine analysis with measurements whenever possible. He received devices (IMPATT oscillators, discrete transistors and Gunn diodes) from Fujitsu and other companies and added his own waveguide, antenna and passive millimeter-wave circuit elements. Using mainly Teflon and quartz, he demonstrated couplers, delay lines, filters, new types of waveguide and leaky wave antennas, and a whole class of millimeter-wave integrated circuit elements [42]–[57]. He also continued working

<sup>7</sup>Y. T. Lo is best known for his work on method of moments and of course for his four volume *Antenna Handbook*, with S.W. Lee, Van Nostrand Reinhold, 1993. He taught at Illinois from 1958 through to his retirement and headed the Electromagnetics Lab from 1982 to 1990.

on his spectral domain transmission line analysis technique and applying it to many new constructs [58]–[61].

By specializing in millimeter-waves, Itoh filled an important niche at Austin. As he branched out and expanded his activities, he was very conscious of trying to establish a reputation. He chose *speed* and *novelty of approach* as his two principle mantras. Early post-docs included Lorenz Peter Schmidt (University of Erlangen), Kiyomichi Araki (Tokyo Institute of Technology) and Ikuo Awai (Yamaguchi University). By 1981 he had risen to full Professor and in 1982 he graduated his first Ph.D. student, Yi-Chi Shih [62], who later founded MMCOMM (now part of Honeywell International) and who is now trying to start a GaN foundry in China. Itoh received a chaired position at Austin in 1983.

Texas proved to be a very good place for Professor Itoh. The department gave him the freedom to pursue whatever course he thought best, and he had a continuous flow of research funding from the Joint Services Electronics Program (JSEP),<sup>8</sup> an extremely well endowed, quality academic research program available at a select number of universities in the U.S. During the period between 1983 and 1990, Itoh worked on a wide variety of microwave and millimeter-wave programs, which laid the groundwork for many techniques later taken up by THz designers. He contributed an amazing 11 book and book chapters [63]–[73], 89 journal papers (25 most cited: [74]–[97] and [62]) and 143 conference papers during this period! He also graduated 23 Ph.D. students, many of who have gone on to prestigious academic careers of their own. Particular results that crossed over to the higher frequency regime include his work on planar transmission lines [63], [67], [68], [80], quasi-optical analysis techniques [72] quasi-optical receiver elements [82], [86], and antennas [94], [97].

Professor Itoh's group at UT Austin typically had 15 students, at least one post-doc, and one or more visiting scientists. He emphasized practical approaches to problem solving and a combination of analysis and implementation. Appropriately, from 1982 to 1985, he took on the role of Editor of the IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, to which he would contribute more than 230 papers over the course of his career. He was also President-elect and President of the IEEE Microwave Theory Techniques Society from 1989 to 1990 and a participant on literally dozens of university and conference organizing committees. He contributed time to many professional organizations, including the International Scientific Radio Union (URSI), especially Commission D (Electronics and Photonics), to which he has devoted more than 35 years of service.

In 1991, Professor Itoh was enticed to leave the University of Texas and relocate at the University of California at Los Angeles

<sup>8</sup>The Joint Services Electronics Program (JSEP) was founded in 1946 by the U.S. Office of Naval Research, the Army Signal Corps and the Air Force. For 50 years it served as a primary funding agency for academic research in all areas of physics and electronics as well as relevant topics in mathematics and biology. JSEP centers were established at the top U.S. universities and funded countless students, faculty and staff on subjects (relevant to THz) as diverse as superconducting tunnel junctions, masers and millimeter-wave radar. The JSEP program was terminated in 1996. *Reference*: Arnold Shostak, "Anniversary of the Joint Services Electronics Program," Defense Technical Information Center, Analytic Services Inc., Arlington, VA, 139 pages, c. 1986.

(UCLA), CA, USA. He attributes his move to recruiting campaigns led by Neville Luhmann (now at UC Davis) and Nicolaos Alexopoulos (then Chair of the Electrical Engineering Department at UCLA, later Dean at UC Irvine). UCLA was particularly interested in getting involved in JSEP, and Itoh brought this association with him. There was also a personal motivation, in that his wife Seiko was still living in the Bay Area, and the move to Los Angeles was a big step in the right direction for reducing the family commuting distance.

If anything, the move to UCLA increased Itoh's work load, and he practically lived in his office. In a typical story, he readily agreed to meet with a visiting colleague who was to be in town only for a few days. Itoh told his visitor to meet him at his office at 11 PM the next evening. Puzzled, but obliging, the colleague came to UCLA at the prescribed time. Itoh arrived shortly afterwards on his way back from the airport after coming in on a long flight from Europe. They talked for three hours and then Itoh headed back to the airport for a flight to Asia early the same morning!

Above and beyond all the writing, teaching, student and staff supervision and traveling, Itoh also was asked, and agreed to assume the role of Editor-in-Chief of a new short-paper journal that had been under development within the IEEE Microwave Theory and Techniques Society for several years. Martin Schneider (Bell Laboratories millimeter-wave and optical engineer and inventor, with Eric Carlson, of the suspended substrate stripline<sup>9</sup>) was instrumental in pushing a new *Letters* style journal to capture the emerging field of sub-millimeter-wave technology. Schneider originally wanted the name *Microwaves-to-Light*<sup>10</sup> to specifically capture the THz regime,<sup>11</sup> but the journal ended up as IEEE MICROWAVE AND GUIDED WAVE LETTERS.<sup>12</sup> Itoh took over as Editor-in-Chief in 1990 and shepherded the new journal through its first four years (1991–1994), at which point it was publishing an average of 120 papers per year. The journal not only took a significant bite of Itoh's time, but it had a physical toll as well. Itoh was forced to divide his UCLA office in half and install a *restricted access* area in order to provide the necessary privacy protections to the submitted manuscripts and the author and reviewer correspondence—which were almost all handled via paper and snail mail!

At UCLA, Itoh focused on active antennas [99]–[104], influenced by Dave Rutledge's group at Caltech [105]–[107] for example, and on planarizing large scale antenna circuits [108]–[111], inspired by the work of Bob York at UC Santa Barbara [112], [113]. True to form, Itoh also tackled a wide

<sup>9</sup>Martin V. Schneider and Eric R. Carlson, "Symmetrical low-loss suspended substrate stripline," U.S. Patent 04 521 755, Bell Laboratories, awarded June 4, 1985.

<sup>10</sup>A name Martin had communicated to the author that he was particularly fond of, but that ultimately would not stick.

<sup>11</sup>In fact the first issue, which only included 4 papers, did have one THz article [98]!

<sup>12</sup>This name too was changed in January 2001 to the current IEEE MICROWAVE AND WIRELESS COMPONENT LETTERS when Samir El-Ghazaly (one of Itoh's former graduate students) assumed the role of Editor-in-Chief. Another THz focused journal did not appear until September 2011, when this publication, IEEE TRANSACTIONS ON TERAHERTZ SCIENCE AND TECHNOLOGY released its Inaugural Issue.

range of other microwave and millimeter-wave topics including superconducting circuits and devices [114]–[116], high speed photodetectors [117], new transmission line structures [118] and components [119], wireless circuits and antennas [120]–[122], and of course, dozens of analytic methods papers of which [123] is just one example.

In 1998, Itoh and his students, Bill Deal and Noriaki Kaneda, along with post-doc Y. Qian, developed a broadband planar antenna [124] derived from the 1927 Uda design [125] (Yagi-Uda), which proved to be extremely useful for high frequency integrated circuit applications. They went on to develop transitions [126], integrated active elements [127] and fully functional planar arrays [128], [129]. A variation of this antenna [130] was later integrated into the first THz MMIC circuits, developed by Bill Deal and his team at Northrop Grumman under a major government Terahertz device and circuit development program [131].

Considering Professor Itoh's mantras of speed and novelty, it is not surprising that he began to take an interest in the emerging field of photonic bandgap (PBG) engineering. Not coincidentally, he was influenced by one of the field's Pioneers, Eli Yablonovitch, who had relocated from Bell Communications Research Laboratory to UCLA's Electrical Engineering department in 1993 (Yablonovitch is now a Professor at UC Berkeley). Itoh started looking at two-dimensional PBG structures composed of various planar antenna designs, frequency selective structures, and purely magnetic surfaces [132]–[141]. He focused on microwave applications and transmission line compatible components. When Christophe Caloz<sup>13</sup> arrived from École Polytechnique Fédérale de Lausanne (EPFL), Switzerland, in October 2000, a dramatic shift in emphasis was just about to take place.

In early 2000, Sheldon Schultz's group at UC San Diego demonstrated the first material with both negative permittivity and negative permeability [142]. The emerging field of metamaterials had become a practical reality [143]!

The emphasis changing breakthrough for Itoh came in 2001, when Valerie Browning at the U.S. Defense Advanced Research Projects Agency (DARPA) and Michele Anderson at the Office of Naval Research (ONR) initiated a MURI (Multi-disciplinary University Research Initiative) program, PI'd out of UC Berkeley, entitled, "Scalable and Reconfigurable Metamaterials." The kick-off meeting on June 5–6, was attended by more than 40 participants from DARPA, ONR, university and industry groups. The principal investigator, Xiang Zhang at Berkeley, and co-PI's Tatsuo Itoh and Eli Yablonovitch at UCLA, John D. Joannopoulos, and Gang Chen at MIT, David Smith and Sheldon Schultz at UC San Diego, and Sir John Pendry at Imperial College, London, UK, formed the implementing teams [144].

Itoh and Caloz decided to deviate from the prevailing physics approach to metamaterials, and to develop "... an engineering approach, based on a generalized transmission line (TL) theory, with symmetric emphasis on developing practical applications..." [145]. They began with the investigation

of these new *left-handed* materials in traditional waveguide configurations [146], and quickly branched out to microstrip and other transmission line structures, antennas, 2D components, slabs and prisms, lenses, surface plasmons and magnetic structures [145]–[157]. Besides their well-read text [145], Itoh and Caloz's most cited work on this subject is their review paper (with UCLA's Anthony Lai) appearing *IEEE Microwave Magazine* in 2004 [158].

During this period, where the focus was on *Left-handed transmission line structures*, Itoh did not falter on his other research areas. He continued to publish book chapters and papers on wireless applications [159], [160], new types of passive antennas [161], active antennas [162], [163], dielectric media [164] and even microwave engineering education [165]. After 2004, Itoh continued to develop and apply his CRLH (composite right and left handed) analysis techniques to a wide variety of problems [166] including leaky wave and resonant antennas [167]–[171], transmission line and waveguide metamaterial components [172]–[174], filters [175]–[177] and other microwave circuits [178].

Most recently, Prof. Itoh has focused his attention on applications of metamaterials to THz quantum cascade lasers [179]–[182], for which he won, along with Philip Hon, Amir Tavallae, Q. S. Chen, and Ben Williams, the 2012 Best Paper award from this journal [183]. He continues to apply his considerable analytic skills to problems in transmission lines and antennas *left and right* [184]–[189], and to project metamaterial application into the future [190].

Prof. Itoh is still teaching 3 classes, attending at least a half dozen meetings and conferences, and publishing more in one year than most of us will in 10. He also sets aside at least an hour each day to respond to the daily requests of hundreds of colleagues. At the end of our chat, Prof. Itoh waxed a bit nostalgic, and suggested that he would like to learn an instrument or to take up a hobby, but he is really hoping for one more hot area to come along to attract his attention. One can only wonder how he will find the time!

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#### REFERENCES

- [1] K. Iijima, Y. Tsuzuki, Y. Hirose, and M. Akiyama, "Laser interferometric measurement of the vibration displacements of a plano-convex AT-cut quartz crystal resonator," *Proc. IEEE*, vol. 64, no. 3, pp. 386–387, Mar. 1976.
- [2] P. W. Smith, "Mode selection in lasers," *Proc. IEEE*, vol. 60, no. 4, pp. 422–440, Apr. 1972.
- [3] W. H. Steier and E. Yamashita, "A pyroelectric effect detector for sub-millimeter wavelengths," *Proc. IEEE*, vol. 51, no. 8, p. 1144, Aug. 1963.
- [4] E. Yamashita and R. Mittra, "Variational method for the analysis of microstrip line," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-16, no. 4, pp. 251–256, Apr. 1968.
- [5] E. Yamashita, R. Mittra, and T. Itoh, "Application of the sampling theorem to a multi-slit coupling structure of a confocal-mirror resonator," *Electron. Lett.*, vol. 5, no. 4, pp. 67–68, Feb. 1969.
- [6] T. Itoh and R. Mittra, "An analytical study of the echelette grating with application to open resonators," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-17, no. 6, pp. 319–329, Jun. 1969.

<sup>13</sup>Christophe Caloz is a well-known figure in the Metamaterials community and is now a Professor at École Polytechnique of Montréal, Canada.

- [7] T. Itoh, "Sub-optical resonators with grating mirrors," Ph.D. dissertation, Dep. Electrical Eng., Univ. Illinois, Urbana-Champaign, Urbana, IL, USA, 1969.
- [8] T. Itoh and R. Mittra, "A method for solving boundary value problems associated with a class of doubly-modified Wiener-Hopf structures," *Proc. IEEE*, vol. 52, no. 12, pp. 2107–2171, Dec. 1969.
- [9] T. Itoh and R. Mittra, "Wood anomalies in diffraction from strip grating," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-18, no. 1, pp. 54–55, Jan. 1970.
- [10] T. Itoh and R. Mittra, "Charge and potential distributions in shielded striplines," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-18, no. 3, pp. 149–156, Mar. 1970.
- [11] T. Itoh and R. Mittra, "An accurate method for calculating charge and potential distributions in coupled microstrip lines," *Proc. IEEE*, vol. 59, no. 2, pp. 332–334, Feb. 1971.
- [12] T. Itoh and R. Mittra, "A new method of solution for radiation from a flanged waveguide," *Proc. IEEE*, vol. 59, no. 7, pp. 1131–1133, Jul. 1971.
- [13] T. Itoh and R. Mittra, "Dispersion characteristics of slot lines," *Electron. Lett.*, vol. 7, no. 13, pp. 364–365, Jul. 1, 1971.
- [14] T. Itoh and R. Mittra, "Relative convergence phenomenon arising in the solution of diffraction from strip grating on dielectric slab," *Proc. IEEE*, vol. 59, no. 9, pp. 1363–1365, Sept. 1971.
- [15] R. Mittra, T. Itoh, and T. S. Li, "Analytical and numerical studies of the relative convergence phenomenon arising in the solution of an integral equation by the moment method," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-20, no. 2, pp. 96–104, Feb. 1972.
- [16] V. Jamnejad, R. Mittra, and T. Itoh, "A comparative study of the rayleigh hypothesis and analytic continuation methods as applied to sinusoidal gratings," *IEEE Trans. Antennas Propag.*, vol. AP-20, no. 3, pp. 392–394, May 1972.
- [17] T. Itoh, R. Mittra, and R. D. Ward, "Method for computing edge capacitance of finite and semi-infinite microstrip lines," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-20, no. 12, pp. 847–849, Dec. 1972.
- [18] T. Itoh and R. Mittra, "New method for calculating capacitance of a circular disk for microwave integrated-circuits," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-21, no. 6, pp. 431–432, Jun. 1973.
- [19] T. Itoh and R. Mittra, "Resonance conditions of open resonators at microwave frequencies," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-22, no. 4, pp. 99–102, Feb. 1974.
- [20] T. Itoh, "A new method for measuring properties of dielectric materials using a microstrip cavity," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-22, no. 5, pp. 572–576, May 1974.
- [21] T. Itoh and R. Mittra, "TEM reflection from a flanged and dielectric-filled parallel-plate waveguide," *Radio Sci.*, vol. 9, no. 10, pp. 849–855, Oct. 1974.
- [22] T. Itoh, "Analysis of microstrip resonators," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-22, no. 11, pp. 946–952, Nov. 1974.
- [23] T. Itoh and R. Mittra, "A method for measuring the refractive index profile of thin film waveguide," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-23, no. 1, pp. 176–177, Jan. 1975.
- [24] M. Mostafavi, T. Itoh, and R. Mittra, "Excitation of an optical fiber by a Gaussian beam," *Appl. Opt.*, vol. 14, no. 9, pp. 2190–2193, Sep. 1975.
- [25] W. McLevige, T. Itoh, and R. Mittra, "New waveguide structures for millimeter wave and optical integrated circuits," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-23, no. 10, pp. 788–794, Oct. 1975.
- [26] T. Itoh, "Inverted strip dielectric waveguide for millimeter-wave integrated circuits," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-24, no. 11, pp. 821–827, Nov. 1976.
- [27] T. Itoh and R. Mittra, "A new technique for the analysis of the dispersion characteristics of microstrip lines," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-19, no. 1, pp. 47–56, Jan. 1971.
- [28] T. Itoh and R. Mittra, "Spectral-domain approach for calculating dispersion characteristics of microstrip lines," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-21, no. 7, pp. 496–499, 1973.
- [29] T. Itoh and R. Mittra, "A technique for computing dispersion characteristics of shielded microstrip lines," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-22, no. 10, pp. 896–898, Oct. 1974.
- [30] R. Mittra and T. Itoh, "Some efficient numerical methods," in *Computer Techniques for Electromagnetics and Antennas*, R. Mittra, Ed. New York: Pergamon, 1973, ch. 6, pp. 305–350.
- [31] R. Mittra and T. Itoh, "Analysis of microstrip lines," in *Microwave Integrated Circuits*, ser. Advances in Microwaves Series, L. Young, Ed. New York: Academic, 1974, pp. 67–141.
- [32] T. Itoh, "Spectral domain immittance approach for dispersion characteristics of generalized printed transmission-lines," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-28, no. 7, pp. 733–736, Jul. 1980.
- [33] T. Itoh, "Electromagnetic insight of Professor Y. T. Lo and his influence on my research career," in *2003 IEEE Int. Symp. on Antennas Propag.*, Columbus, OH, USA, Jun. 23–27, 2003, pp. 416–419.
- [34] M. S. McPherson, "The demand for new faculty in science and engineering," in *Proc. Workshop of Specialists in Forecasts of Demand for Scientists and Engineers*, 1979, p. 116.
- [35] T. Itoh, "Application of gratings in a dielectric waveguide for leaky-wave antenna and band-reject filter," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-25, no. 12, pp. 1134–1138, Dec. 1977.
- [36] T. Itoh and A. S. Herbert, "A generalized spectral domain analysis for coupled suspended microstrip lines with tuning septums," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-26, no. 10, pp. 820–826, Oct. 1978.
- [37] T. Itoh, "Generalized spectral domain method for multi-conductor printed lines and its application to tunable suspended microstrips," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-26, no. 12, pp. 983–987, Dec. 1978.
- [38] T. Itoh and A. S. Herbert, "Simulation study of electronically scannable antennas and tunable filters integrated in a quasi-planar dielectric waveguide," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-26, no. 12, pp. 987–991, Dec. 1978.
- [39] T. Itoh and F. J. Hsu, "Distributed bragg reflector gunn oscillators for dielectric millimeter-wave integrated circuits," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-27, no. 5, pp. 514–518, May 1979.
- [40] T. Itoh and F. J. Hsu, "Application of inverted strip dielectric waveguide for measurement of the dielectric constant of low-loss materials at millimeter-wave frequencies," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-27, no. 10, pp. 841–844, Oct. 1979.
- [41] B. S. Song and T. Itoh, "Distributed bragg reflection dielectric waveguide oscillators," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-27, no. 12, pp. 1019–1022, Dec. 1979.
- [42] T. Itoh and B. Adelseck, "Trapped image guide for millimeter-wave circuits," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-28, no. 28, pp. 1433–1436, Dec. 1980.
- [43] K. Araki and T. Itoh, "Hankel transform domain analysis of open circular microstrip radiating structures," *IEEE Trans. Antennas Propag.*, vol. AP-29, no. 1, pp. 84–90, Jan. 1981.
- [44] I. Awai and T. Itoh, "Multilayered open dielectric waveguide with a gyrotropic layer," *Int. J. Infrared Millim. Waves*, vol. 2, no. 3, pp. 427–436, May 1981.
- [45] L. P. Schmidt, T. Itoh, and H. Hofmann, "Characteristics of unilateral fin-line structures with arbitrarily located slots," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-29, no. 4, pp. 352–355, Apr. 1981.
- [46] L. P. Schmidt and T. Itoh, "Characteristics of a generalized fin-line for millimeter-wave integrated circuits," *Int. J. Infrared and Millim. Waves*, vol. 2, no. 3, pp. 427–436, May 1981.
- [47] K. Araki and T. Itoh, "Analysis of periodic ferrite slab waveguides by means of improved perturbation method," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-29, no. 9, pp. 911–916, Sep. 1981.
- [48] I. Awai and T. Itoh, "An analysis of distributed gunn effect devices with subcritical doping," *Int. J. Infrared Millim. Waves*, vol. 2, no. 5, pp. 883–904, Sept. 1981.
- [49] T. Itoh and B. Adelseck, "Trapped image guide leaky-wave antenna for millimeter wave applications," *IEEE Trans. Antennas Propag.*, vol. AP-30, no. 3, pp. 505–509, May 1982.
- [50] Y. C. Shih and T. Itoh, "Analysis of conductor-backed coplanar waveguide," *Electron. Lett.*, vol. 18, no. 12, pp. 538–540, Jun. 10, 1982.
- [51] Y. Fukuoka and T. Itoh, "Analysis of slow-wave phenomena in coplanar waveguide on a semi-conductor substrate," *Electron. Lett.*, vol. 18, no. 14, pp. 589–590, Jul. 18, 1982.
- [52] N. Camilleri and T. Itoh, "An analysis of wave phenomena in a dielectric waveguide with periodic metal strips," *Int. J. Infrared Millim. Waves*, vol. 3, no. 4, pp. 541–551, Jul. 1982.
- [53] T. Itoh, "Open guiding structures for millimeter-wave integrated circuits," *Microw. J.*, vol. 25, no. 9, pp. 113–126, Sept. 1982.
- [54] J.-F. Miao and T. Itoh, "Hollow image guide and overlaid image guide coupler," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-30, no. 11, pp. 1826–1831, Nov. 1982.
- [55] W. B. Zhou and T. Itoh, "Analysis of trapped image guides using effective dielectric constants and surface impedances," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-30, no. 12, pp. 2163–2166, Dec. 1982.
- [56] Y. Fukuoka and T. Itoh, "Slow-wave propagation on MIS periodic coplanar waveguide," *Electron. Lett.*, vol. 19, no. 2, pp. 37–38, Jan. 20, 1983.
- [57] T. Itoh, "Dielectric waveguide type millimeter-wave integrated circuits," in *Infrared and Millimeter Waves*, K. Button and J. C. Wiltse, Eds. New York: Academic Press, 1981, vol. 5, ch. 5, pp. 199–273.

- [58] L. P. Schmidt and T. Itoh, "Spectral domain analysis of dominant and higher order modes in fin-lines," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-28, no. 9, pp. 981–985, Sep. 1980.
- [59] T. Itoh and W. Menzel, "A full-wave analysis method for open microstrip structures," *IEEE Trans. Antennas Propag.*, vol. AP-29, no. 1, pp. 63–68, Jan. 1981.
- [60] I. Awai and T. Itoh, "Coupled-mode theory analysis of distributed non-reciprocal structures," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-29, no. 10, pp. 1079–1087, Oct. 1981.
- [61] Y. C. Shih and T. Itoh, "Analysis of printed transmission lines for monolithic integrated circuits," *Electron. Lett.*, vol. 18, no. 14, pp. 585–586, Jul. 18, 1982.
- [62] Y. C. Shih, T. Itoh, and L. O. Bui, "Computer-aided design of millimeter-wave E-plane filters," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-31, no. 2, pp. 135–142, Feb. 1983.
- [63] T. Itoh and J. Rivera, "Comparative studies of millimeter wave transmission lines," in *Infrared and Millimeter Waves*, K. Button, Ed. New York: Academic Press, 1983, vol. 9, ch. 2, pp. 95–132.
- [64] T. Itoh, "Transmission Lines," in *Reference Data for Radio Engineers*, E. C. Jordan, Ed., 7th ed. Indianapolis, IN, USA: Howard W. Sams, 1985, ch. 29, pp. 29.1–29.37.
- [65] T. Itoh, "Spectral domain approach," in *Recent Advances in Numerical Methods for Electromagnetics* (in Japanese), E. Yamashita, Ed. Tokyo: Inst. Electron., Inf. and Commun. Eng. Japan, 1987, ch. 11, pp. 339–364.
- [66] T. Itoh, "Waveguides and resonators," in *Reference Data for Radio Engineers*, E. C. Jordan, Ed., 7th ed. Indiana, IN, USA: Howard W. Sams, 1985, ch. 30, pp. 30.1–30.30.
- [67] T. Itoh, Ed., *Planar Transmission Line Structures*. New York: IEEE Press, 1987.
- [68] T. Itoh, Ed., *Numerical Techniques for Microwave and Millimeter-Wave Passive Structures*. New York, NY, USA: Wiley Interscience, 1989.
- [69] T. Itoh, "Introduction and Overview," in *Numerical Techniques for Microwave and Millimeter-Wave Passive Structures*. New York, NY, USA: Wiley Interscience, 1989, ch. 1, pp. 1–32.
- [70] T. Uwano and T. Itoh, "Spectral Domain Approach," in *Numerical Techniques for Microwave and Millimeter-Wave Passive Structures*, T. Itoh, Ed. New York, NY, USA: Wiley Interscience, 1989, ch. 5, pp. 334–380.
- [71] T. Itoh, "Generalized Scattering Matrix Technique," in *Numerical Techniques for Microwave and Millimeter-Wave Passive Structures*, T. Itoh, Ed. New York, NY, USA: Wiley Interscience, 1989, ch. 10, pp. 622–636.
- [72] P. F. Goldsmith, T. Itoh, and K. D. Stephan, "Quasi-optical techniques," in *Handbook of Microwave and Optical Components*, K. Chang, Ed. New York, NY, USA: Wiley Interscience, 1989, vol. 1, ch. 7, pp. 344–363.
- [73] T. Itoh, "The spectral domain method," in *Analysis Method for Electromagnetic Wave Problems*, E. Yamashita, Ed. Boston, MA, USA: Artech House, 1990, ch. 11, pp. 371–398.
- [74] H. Y. Lee and T. Itoh, "Phenomenological loss equivalence method for planar quasi-TEM transmission-lines with a thin normal conductor or superconductor," *IEEE Trans. Microw. Theory Techn.*, vol. 37, no. 12, pp. 1904–1909, Dec. 1989.
- [75] Y. Fukuoka, Y. C. Shih, and T. Itoh, "Analysis of slow-wave coplanar waveguide for monolithic integrated-circuits," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-31, no. 7, pp. 567–573, Jul. 1983.
- [76] C.-Y. Chang and T. Itoh, "Microwave active filters based on coupled negative resistance method," *IEEE Trans. Microw. Theory Techn.*, vol. 38, no. 12, pp. 1879–1884, Dec. 1990.
- [77] T. S. Chu and T. Itoh, "Generalized scattering matrix-method for analysis of cascaded and offset microstrip step discontinuities," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-34, no. 2, pp. 280–284, Feb. 1986.
- [78] T. S. Chu, T. Itoh, and Y. C. Shih, "Comparative-study of mode-matching formulations for microstrip discontinuity problems," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-33, no. 10, pp. 1018–1023, Oct. 1985.
- [79] R. Sorrentino and T. Itoh, "Transverse resonance analysis of finline discontinuities," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-32, no. 12, pp. 1633–1638, Dec. 1984.
- [80] T. Itoh, "Overview of quasi-planar transmission-lines," *IEEE Trans. Microw. Theory Techn.*, vol. 37, no. 2, pp. 275–280, Feb. 1989.
- [81] L. Q. Bui, D. Ball, and T. Itoh, "Broad-band millimeter-wave E-plane bandpass-filters," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-32, no. 12, pp. 1655–1658, Dec. 1984.
- [82] K. D. Stephan, N. Camilleri, and T. Itoh, "A quasi-optical polarization-duplexed balanced mixer for millimeter-wave applications," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-31, no. 2, pp. 164–170, 1983.
- [83] T. C. Mu, H. Ogawa, and T. Itoh, "Characteristics of multiconductor, asymmetric, slow-wave microstrip transmission-lines," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-34, no. 12, pp. 1471–1477, Dec. 1986.
- [84] Y. C. Shih and T. Itoh, "E-plane filters with finite-thickness septa," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-31, no. 12, pp. 1009–1013, Dec. 1983.
- [85] C. K. Tzuang and T. Itoh, "Finite-element analysis of slow-wave Schottky contact printed lines," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-34, no. 12, pp. 1483–1489, Dec. 1986.
- [86] K. D. Stephan and T. Itoh, "A planar quasi-optical subharmonically pumped mixer characterized by isotropic conversion loss," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-32, no. 1, pp. 97–102, Jan. 1984.
- [87] M. Geshiro and T. Itoh, "Analysis of double-layered finlines containing a magnetized ferrite," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-35, no. 12, pp. 1377–1381, Dec. 1987.
- [88] Y. Fukuoka, Q. Zhang, D. P. Neikirk, and T. Itoh, "Analysis of multi-layer interconnection lines for a high-speed digital integrated-circuit," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-33, no. 6, pp. 527–532, Jun. 1985.
- [89] Q. Zhang and T. Itoh, "Spectral-domain analysis of scattering from E-plane circuit elements," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-35, no. 2, pp. 138–150, Feb. 1987.
- [90] P. Cheung, D. P. Neikirk, and T. Itoh, "Optically controlled coplanar wave-guide phase shifters," *IEEE Trans. Microw. Theory Techn.*, vol. 38, no. 5, pp. 586–595, May 1990.
- [91] V. D. Hwang and T. Itoh, "Quasi-optical HEMT and MESFET self-oscillating mixers," *IEEE Trans. Microw. Theory Techn.*, vol. 36, no. 12, pp. 1701–1705, Dec. 1988.
- [92] H. Ogawa and T. Itoh, "Slow-wave characteristics of ferromagnetic semiconductor microstrip line," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-34, no. 12, pp. 1478–1482, Dec. 1986.
- [93] V. P. Kesan, A. Mortazawi, D. R. Miller, V. K. Reddy, D. P. Neikirk, and T. Itoh, "Microwave and millimeter-wave QWITT diode oscillators," *IEEE Trans. Microw. Theory Techn.*, vol. 37, no. 12, pp. 1933–1941, Dec. 1989.
- [94] V. D. Hwang, T. Uwano, and T. Itoh, "Quasi-optical integrated antenna and receiver front end," *IEEE Trans. Microw. Theory Techn.*, vol. 36, no. 1, pp. 80–85, Jan. 1988.
- [95] B. Young and T. Itoh, "Analysis and design of microslab wave-guide," *IEEE Trans. Microw. Theory Techn.*, vol. MTT-35, no. 9, pp. 850–857, Sep. 1987.
- [96] J. Birkeland and T. Itoh, "Planar FET oscillators using periodic microstrip patch antennas," *IEEE Trans. Microw. Theory Techn.*, vol. 37, no. 8, pp. 1232–1236, Aug. 1989.
- [97] S. M. Wentworth, R. L. Rogers, J. G. Heston, D. P. Neikirk, and T. Itoh, "Millimeter wave twin slot antennas on layered substrates," *Int. J. Infrared Millim. Waves*, vol. 11, no. 2, pp. 111–131, Feb. 1990.
- [98] P. H. Siegel, R. J. Dengler, and J. C. Chen, "THz dichroic plates for high angles of incidence," *IEEE Microw. Guided Wave Lett.*, vol. 1, no. 1, pp. 8–9, Jan. 1991.
- [99] J. Birkeland and T. Itoh, "A 16 element quasi-optical FET oscillator power combining array with external injection locking," *IEEE Trans. Microw. Theory Techn.*, vol. 40, no. 3, pp. 475–481, Mar. 1992.
- [100] A. Mortazawi, H. D. Foltz, and T. Itoh, "A periodic 2nd harmonic spatial power combining oscillator," *IEEE Trans. Microw. Theory Techn.*, vol. 40, no. 5, pp. 851–856, May 1992.
- [101] S. Kawasaki and T. Itoh, "Quasi-optical planar arrays with FETS and slots," *IEEE Trans. Microw. Theory Techn.*, vol. 41, no. 10, pp. 1838–1844, Oct. 1993.
- [102] J. Lin and T. Itoh, "Two-dimensional quasi-optical power-combining arrays using strongly coupled oscillators," *IEEE Trans. Microw. Theory Techn. (Special Section on Space THz Technol.)*, vol. 42, no. 4, pp. 734–741, Apr. 1994.
- [103] M. Minegishi, J. S. Lin, T. Itoh, and S. Kawasaki, "Control of mode-switching in an active antenna using MESFET," *IEEE Trans. Microw. Theory Techn.*, vol. 43, no. 8, pp. 1869–1874, Aug. 1995.
- [104] W. R. Deal, V. Radisic, Y. Qian, and T. Itoh, "Active and high-performance antennas," in *RF Technologies for Low Power Wireless Communications*. New York, NY, USA: Wiley, 2001, ch. 9, pp. 305–348.
- [105] W. W. Lam, C. F. Jou, N. C. Luhmann, and D. B. Rutledge, "Diode grids for electronic beam steering and frequency multiplication," *Int. J. Infrared Millim. Waves*, vol. 7, no. 1, pp. 27–41, Jan. 1986.

- [106] Z. B. Popovic, M. Kim, and D. B. Rutledge, "Grid Oscillators," *Int. Journal of Infrared Millim. Waves*, vol. 9, no. 11, pp. 1003–1010, Nov. 1988.
- [107] Z. B. Popovic, R. M. Weikle, M. Kim, and D. B. Rutledge, "A 100-MESFET Planar Grid Oscillator," *IEEE Trans. Microw. Theory Techn.*, vol. 39, no. 2, pp. 193–200, Feb. 1991.
- [108] J. S. Lin and T. Itoh, "Active integrated antennas," *IEEE Trans. Microw. Theory Techn.*, vol. 42, no. 12, pp. 2186–2194, Dec. 1994.
- [109] S. T. Chew, D. T. K. Tong, M. C. Wu, and T. Itoh, "Active antenna array with optical interaction for application in radar system," in *1995 IEEE MTT-S Int. Microw. Symp. Dig.*, L. Kirby, Ed., 1995, vol. 1–3, pp. 1221–1224.
- [110] S. T. Chew, D. T. K. Tong, M. C. Wu, and T. Itoh, "Optically assisted microwave active integrated antennas," *IEICE Trans. Electron.*, vol. E79C, no. 1, pp. 60–67, Jan. 1996.
- [111] Y. X. Qian and T. Itoh, "Progress in active integrated antennas and their applications," *IEEE Trans. Microw. Theory Techn.*, vol. 46, no. 11, pp. 1891–1900, Nov. 1998.
- [112] R. A. York and T. Itoh, "Injection- and phase-locking techniques for beam control," *IEEE Trans. Microw. Theory Techn.*, vol. 46, no. 11, pp. 1920–1929, Nov. 1998.
- [113] K. Chang, R. A. York, P. S. Hall, and T. Itoh, "Active integrated antennas," *IEEE Trans. Microw. Theory Techn.*, vol. 50, no. 3, pp. 937–944, Mar. 2002.
- [114] C. M. Chorey, K. S. Kong, K. B. Bhasin, J. D. Warner, and T. Itoh, "YBCO superconducting ring resonators at millimeter-wave frequencies," *IEEE Trans. Microw. Theory Techn.*, vol. 39, no. 9, pp. 1480–1487, Sep. 1991.
- [115] S. M. El Ghazaly, R. B. Hammond, and T. Itoh, "Analysis of superconducting microwave structures—Application to microstrip lines," *IEEE Trans. Microw. Theory Techn.*, vol. 40, no. 3, pp. 499–508, Mar. 1992.
- [116] O. R. Baiocchi, K. S. Kong, and T. Itoh, "Pulse-propagation in superconducting coplanar striplines," *IEEE Trans. Microw. Theory Techn.*, vol. 40, no. 3, pp. 509–514, Mar. 1992.
- [117] L. Y. Lin, M. C. Wu, T. Itoh, T. A. Vang, R. E. Muller, D. L. Sivco, and A. Y. Cho, "High-power high-speed photodetectors—Design, analysis, and experimental demonstration," *IEEE Trans. Microw. Theory Techn.*, vol. 45, no. 8, pp. 1320–1331, Aug. 1997.
- [118] B. Toland and T. Itoh, "Boundary element analysis of a trapezoidal transmission line," *IEEE Trans. Microw. Theory Techn.*, vol. 41, no. 6, pp. 1052–1056, Jun. 1993.
- [119] D.-C. Niu, T. Yoneyama, and T. Itoh, "Analysis and measurement of NRD-guide leaky wave coupler in Ka-band," *IEEE Trans. Microw. Theory Techn.*, vol. 41, no. 12, pp. 2126–2132, Dec. 1993.
- [120] C. Pobanz and T. Itoh, "Quasi-optical microwave circuits for wireless applications," *Microw. J.*, pp. 64–85, Jan. 1995.
- [121] C. Pobanz and T. Itoh, "A microwave non-contact identification transponder using subharmonic interrogation," *IEEE Trans. Microw. Theory Techn. (Special Issue on Commercial and Consumer Circuits, Syst., Appl.)*, vol. 43, no. 7, pp. 1673–1679, Jul. 1995.
- [122] A. Basu and T. Itoh, "Millimeter-wave antennas," *Ann. Telecommun.*, vol. 52, no. 3–4, pp. 178–187, Mar.–Apr. 1997.
- [123] T. Shibata and T. Itoh, "Generalized-scattering-matrix modeling of waveguide circuits using FDTD field simulations," *IEEE Trans. Microw. Theory Techn.*, vol. 46, no. 11, pp. 1742–1751, Nov. 1998.
- [124] Y. Qian, W. R. Deal, N. Kaneda, and T. Itoh, "Microstrip-fed quasi-Yagi antenna with broadband characteristics," *Electron. Lett.*, vol. 34, no. 23, pp. 2194–2196, Nov. 1998.
- [125] D. M. Pozar, H. Yagi, Ed., "Beam transmission of ultra short waves: An introduction to the classic paper," *Proc. IEEE*, vol. 85, no. 11, pp. 1857–1863, Nov. 1997.
- [126] N. Kaneda, Y. X. Qian, and T. Itoh, "A broad-band microstrip-to-waveguide transition using quasi-Yagi antenna," *IEEE Trans. Microw. Theory Techn.*, vol. 47, no. 12, pp. 2562–2567, Dec. 1999.
- [127] W. R. Deal, N. Kaneda, J. Sor, Y. X. Qian, and T. Itoh, "A new quasi-Yagi antenna for planar active antenna arrays," *IEEE Trans. Microw. Theory Techn.*, vol. 48, no. 6, pp. 910–918, Jun. 2000.
- [128] W. R. Deal, J. Sor, R. Y. Miyamoto, Y. Qian, and T. Itoh, "A sixteen element quasi-Yagi antenna array with Chebyshev excitation coefficients," in *IEEE Int. Symp. on Antennas and Propag. (AP2000)*, Davos, Switzerland, Apr. 10–14, 2000, Session 5A4.
- [129] K. Leong, J. Sor, W. R. Deal, Y. X. Qian, and T. Itoh, "A broadband 64-element 2-D quasi-Yagi antenna array," in *IEEE Radio and Wireless Conf. (RAWCON 2000)*, Denver, CO, Sep. 10–13, 2000, pp. 67–70.
- [130] N. Kaneda, W. R. Deal, Y. X. Qian, R. Waterhouse, and T. Itoh, "A broad-band planar quasi-Yagi antenna," *IEEE Trans. Antennas Propag.*, vol. 50, no. 8, pp. 1158–1160, Aug. 2002.
- [131] W. Deal, private communication.
- [132] V. Radisic, Y. X. Qian, and T. Itoh, "Broad-band power amplifier using dielectric photonic bandgap structure," *IEEE Microw. Guided Wave Letters*, vol. 8, no. 1, pp. 13–14, Jan. 1998.
- [133] V. Radisic, Y. X. Qian, R. Coccioli, and T. Itoh, "Novel 2-D photonic bandgap structure for microstrip lines," *IEEE Microw. Guided Wave Letters*, vol. 8, no. 2, pp. 69–71, Feb. 1998.
- [134] F. R. Yang, Y. X. Qian, R. Coccioli, and T. Itoh, "Analysis and application of photonic band-gap (PBG) structures for microwave circuits," *Electromagnetics*, vol. 19, no. 3, pp. 241–254, May–Jun. 1999.
- [135] F. R. Yang, K. P. Ma, Y. X. Qian, and T. Itoh, "A uniplanar compact photonic-bandgap (UC-PBG) structure and its applications for microwave circuits," *IEEE Trans. Microw. Theory Techn.*, vol. 47, no. 8, pp. 1509–1514, Aug. 1999.
- [136] F. R. Yang, K. P. Ma, Y. X. Qian, and T. Itoh, "A novel TEM waveguide using uniplanar compact photonic-bandgap (UC-PBG) structure," *IEEE Trans. Microw. Theory Techn.*, vol. 47, no. 11, pp. 2092–2098, Nov. 1999.
- [137] R. Coccioli, F. R. Yang, K. P. Ma, and T. Itoh, "Aperture-coupled patch antenna on UC-PBG substrate," *IEEE Trans. Microw. Theory Techn.*, vol. 47, no. 11, pp. 2123–2130, Nov. 1999.
- [138] F.-R. Yang, R. Coccioli, Y. Qian, and T. Itoh, "Planar PBG structures: Basic properties and applications," *IEICE Trans. Electronics*, vol. E83-C, no. 5, pp. 687–695, May 2000.
- [139] S. T. Chew and T. Itoh, "PBG-excited split-mode resonator bandpass filter," *IEEE Microwave & Wireless Components Letters*, vol. 11, no. 9, pp. 364–366, Sept. 2001.
- [140] D. Ahn, J. S. Park, C. S. Kim, J. Kim, Y. X. Qian, and T. Itoh, "A design of the low-pass filter using the novel microstrip defected ground structure," *IEEE Trans. Microw. Theory Techn.*, vol. 49, no. 1, pp. 86–93, Jan. 2001.
- [141] C.-C. Chang and T. Itoh, "Planar microwave photonic bandgap structures," in *Photonic Crystals—Application, Technology and Physics*, S. Kawakami, Ed. Tokyo, Japan: CMC Books, 2002, ch. 5, pp. 63–79.
- [142] D. R. Smith, D. C. Vier, W. Padilla, S. C. Nemet-Nasser, and S. Schultz, "Composite medium with simultaneous negative permeability and permittivity," *Phys. Rev. Lett.*, vol. 84, no. 18, pp. 4184–4187, May 2000.
- [143] P. H. Siegel, "Sir John Pendry—Theoretical physics for a practical world," *IEEE Trans. THz Sci. Technol.*, vol. 3, no. 6, pp. 689–698, Nov. 2013.
- [144] X. Zhang, DOD/ONR MURI, Scalable and Reconfigurable Metamaterials MURI Quarterly Report, Jun. 1–Aug. 31 2001 [Online]. Available: <http://xlab-new.berkeley.edu/MURI/Kickoff/MURI-report-Q1-2001.pdf>, UCLA, 6 pages, available from the web at:
- [145] C. Caloz and T. Itoh, *Electromagnetic Metamaterials—Transmission Line Theory and Microwave Applications*. : Wiley-Interscience, 2006, p. 352, Quote from page xiii.
- [146] C. Caloz, C. C. Chang, and T. Itoh, "Full-wave verification of the fundamental properties of left-handed materials in waveguide configurations," *Journal of Appl. Phys.*, vol. 90, no. 11, pp. 5483–5486, Dec. 2001.
- [147] C. Caloz and T. Itoh, "Multilayer and anisotropic planar compact PBG structures for microstrip applications," *IEEE Trans. Microw. Theory Techn.*, vol. 50, no. 9, pp. 2206–2208, Sept. 2002.
- [148] C. Caloz and T. Itoh, "Left-handed transmission lines and equivalent metamaterials for microwave and millimeter-wave applications," in *32nd European Microwave Conf. Proc.*, Milan, Italy, Sept. 23–27, 2002, pp. 323–326.
- [149] L. Liu, C. Caloz, and T. Itoh, "Dominant mode leaky-wave antenna with backfire-to-endfire scanning capability," *Electron. Lett.*, vol. 38, no. 23, pp. 1414–1416, Nov. 2002.
- [150] L. Liu, C. Caloz, C.-C. Chang, and T. Itoh, "Forward coupling phenomena between artificial left-handed transmission lines," *J. Appl. Phys.*, vol. 92, no. 9, pp. 5560–5565, Nov. 1, 2002.
- [151] C. Caloz and T. Itoh, "Positive/negative refractive index anisotropic 2-D metamaterials," *IEEE Microw. Wireless Components Letters*, vol. 13, no. 12, pp. 547–549, Dec. 2003.
- [152] A. Sanada, C. Caloz, and T. Itoh, "Characteristics of the composite right/left-handed transmission lines," *Microw. Wireless Components Letters*, vol. 14, no. 2, pp. 68–70, Feb. 2004.
- [153] C. Caloz, A. Sanada, and T. Itoh, "A novel composite right-/left-handed coupled-line directional coupler with arbitrary coupling level and broad bandwidth," *IEEE Trans. Microw. Theory Techn.*, vol. 52, no. 3, pp. 980–992, Mar. 2004.
- [154] I. H. Lin, M. De Vincentis, C. Caloz, and T. Itoh, "Arbitrary dual-band components using composite right/left-handed transmission lines," *IEEE Trans. Microw. Theory Techn.*, vol. 52, no. 4, pp. 1142–1149, Apr. 2004.



- [155] A. Sanada, C. Caloz, and T. Itoh, "Planar distributed structures with negative refractive index," *IEEE Trans. Microw. Theory Techn.*, vol. 52, no. 4, pp. 1252–1263, Apr. 2004.
- [156] C. Caloz and T. Itoh, "Transmission line approach of left-handed (LH) materials and microstrip implementation of an artificial LH transmission line," *IEEE Trans. Antennas Propag.*, vol. 52, no. 5, pp. 1159–1166, May 2004.
- [157] S. Lim, C. Caloz, and T. Itoh, "Metamaterial-based electronically controlled transmission-line structure as a novel leaky-wave antenna with tunable radiation angle and beamwidth," *IEEE Trans. Microw. Theory Techn.*, vol. 52, no. 12, pp. 2678–2690, Dec. 2004.
- [158] A. Lai, C. Caloz, and T. Itoh, "Composite right/left-handed transmission line metamaterials," *IEEE Microwave Magazine*, vol. 5, no. 3, pp. 34–50, Sept. 2004.
- [159] T. Itoh, G. Haddad, and J. Harvey, Eds., *RF Technologies for Low Power Wireless Communications*. New York, NY: John Wiley & Sons, 2001.
- [160] R. Y. Miyamoto, Y. Qian, and T. Itoh, "An active integrated retrodirective transponder for remote information retrieval-on-demand," *IEEE Trans. Microw. Theory Techn.*, vol. 49, no. 9, pp. 1658–1662, Sept. 2001.
- [161] J.-Y. Park, C. Caloz, Y. Qian, and T. Itoh, "A compact circularly polarized subdivided microstrip patch antenna," *IEEE Microw. Wireless Component Letters*, vol. 12, no. 1, pp. 18–19, Jan. 2002.
- [162] J. D. Fredrick and T. Itoh, "Antennas V: Active integrated antennas," in *Handbook of RF/Microwave Components and Engineering*, K. Chang, Ed. Hoboken, NJ, USA: Wiley-Interscience, 2003, ch. 13, pp. 905–922.
- [163] W. R. Deal, V. Radisic, Y. Qian, and T. Itoh, "Microwave active circuits and integrated antennas," in *The Electrical Engineering Handbook*, W.-K. Chen, Ed. Cambridge, MA, USA: Elsevier, 2005, ch. 11, pp. 691–706.
- [164] S. J. Fiedruszko, I. C. Hunter, T. Itoh, Y. Kobayashi, T. Nishikawa, S. N. Stitzer, and K. Wakino, "Dielectric materials, devices and circuits," *IEEE Trans. Microw. Theory Techn.*, vol. 50, no. 3, pp. 706–720, Mar. 2002.
- [165] K. C. Gupta, T. Itoh, and A. A. Oliner, "Microwave and RF education—Past, present and future," *IEEE Trans. Microw. Theory Techn.*, vol. 50, no. 3, pp. 1006–1014, Mar. 2002.
- [166] C. Caloz and T. Itoh, "Metamaterials for high-frequency electronics," *Proc. IEEE*, vol. 93, no. 10, pp. 1744–1752, Oct. 2005.
- [167] S. Lim, C. Caloz, and T. Itoh, "Metamaterial-based electronically controlled transmission-line structure as a novel leaky-wave antenna with tunable radiation angle and beamwidth," *IEEE Trans. Microw. Theory Techn.*, vol. 53, no. 1, pp. 161–173, Jan. 2005.
- [168] C. J. Lee, K. Leong, and T. Itoh, "Composite right/left-handed transmission line based compact resonant antennas for RF module integration," *IEEE Trans. Antennas Propag.*, vol. 54, no. 8, pp. 2283–2291, Aug. 2006.
- [169] A. Lai, K. M. K. H. Leong, and T. Itoh, "Infinite wavelength resonant antennas with monopolar radiation pattern based on periodic structures," *IEEE Trans. Antennas Propag.*, vol. 55, no. 3, pp. 868–876, Mar. 2007.
- [170] C. Caloz, T. Itoh, and A. Rennings, "CRLH metamaterial leaky-wave and resonant antennas," *IEEE Antennas Propag. Mag.*, vol. 50, no. 5, pp. 25–39, Oct. 2008.
- [171] A. Lai, C. J. Lee, and T. Itoh, "Metamaterials for antenna applications," in *Advanced Millimeter-wave Technologies, Antennas, Packaging and Circuits*, D. Liu, B. Gaucher, U. Pfeiffer, and J. Grzyb, Eds. Chichester, U.K.: Wiley, 2009, ch. 9, pp. 385–412.
- [172] Y. Horii, C. Caloz, and T. Itoh, "Super-compact multilayered left-handed transmission line and diplexer application," *IEEE Trans. Microw. Theory Techn.*, vol. 53, no. 4, pp. 1527–1534, Apr. 2005.
- [173] P. L. Chi and T. Itoh, "Miniaturized dual-band directional couplers using composite right/left-handed transmission structures and their applications in beam pattern diversity systems," *IEEE Trans. Microw. Theory Techn.*, vol. 57, no. 5, pp. 1207–1215, May 2009.
- [174] I. H. Lin, K. Leong, C. Caloz, and T. Itoh, "Dual-band sub-harmonic quadrature mixer using composite right/left-handed transmission lines," *IEE Proc.-Microwaves Antennas Propag.*, vol. 153, no. 4, pp. 365–375, Aug. 2006.
- [175] S. J. Wu, C. H. Tsai, T. L. Wu, and T. Itoh, "A novel wideband common-mode suppression filter for gigahertz differential signals using coupled patterned ground structure," *IEEE Trans. Microw. Theory Techn.*, vol. 57, no. 4, pp. 848–855, Apr. 2009.
- [176] Y. D. Dong, T. Yang, and T. Itoh, "Substrate integrated waveguide loaded by complementary split-ring resonators and Its applications to miniaturized waveguide filters," *IEEE Trans. Microw. Theory Techn.*, vol. 57, no. 9, pp. 2211–2223, Sep. 2009.
- [177] T. Yang, M. Tamura, and T. Itoh, "Compact hybrid resonator with series and shunt resonances used in miniaturized filters and balun filters," *IEEE Trans. Microw. Theory Techn.*, vol. 58, no. 2, pp. 390–402, Feb. 2010.
- [178] T. Yang, P. L. Chi, and T. Itoh, "Compact quarter-wave resonator and Its applications to miniaturized diplexer and triplexer," *IEEE Trans. Microw. Theory Techn.*, vol. 59, no. 2, pp. 260–269, Feb. 2011.
- [179] A. A. Tavallae, P. C. Hon, K. Mehta, T. Itoh, and B. S. Williams, "Zero-index terahertz quantum-cascade metamaterial lasers," *IEEE Journal of Quantum Electronics*, vol. 46, no. 7, pp. 1091–1098, Jul. 2010.
- [180] A. A. Tavallae, B. S. Williams, P. W. C. Hon, T. Itoh, and Q. S. Chen, "Terahertz quantum-cascade laser with active leaky-wave antenna," *Appl. Phys. Lett.*, vol. 99, no. 14, Oct. 2011.
- [181] A. A. Tavallae, P. W. C. Hon, Q. S. Chen, T. Itoh, and B. S. Williams, "Active terahertz quantum-cascade composite right/left-handed metamaterial," *Appl. Phys. Lett.*, vol. 102, no. 2, Jan. 2013.
- [182] Z. J. Liu, P. W. C. Hon, A. A. Tavallae, T. Itoh, and B. S. Williams, "Terahertz composite right-left handed transmission-line metamaterial waveguides," *Appl. Phys. Lett.*, vol. 100, no. 7, Feb. 2012.
- [183] P. W. C. Hon, Z. J. Liu, T. Itoh, and B. S. Williams, "Leaky and bound modes in terahertz metasurfaces made of transmission-line metamaterials," *J. Appl. Phys.*, vol. 113, no. 3, Jan. 2013.
- [184] P. W. C. Hon, A. A. Tavallae, Q. S. Chen, B. S. Williams, and T. Itoh, "Radiation model for terahertz transmission-line metamaterial quantum-cascade lasers," *IEEE Trans. THz Sci. Technol.*, vol. 2, no. 3, pp. 323–332, May 2012.
- [185] P. W. C. Hon, A. Ayazi, B. Jalali, and T. Itoh, "Dielectric field enhancer for reconfiguring the beam pattern and gain of an antenna," *IEEE Trans. Antennas Propag.*, vol. 60, no. 9, pp. 4426–4429, Sep. 2012.
- [186] D. R. Jackson, C. Caloz, and T. Itoh, "Leaky-wave antennas," *Proc. IEEE*, vol. 100, no. 7, pp. 2194–2206, Jul. 2012.
- [187] Y. D. Dong and T. Itoh, "Metamaterial-based antennas," *Proc. IEEE*, vol. 100, no. 7, pp. 2271–2285, Jul. 2012.
- [188] Y. D. Dong and T. Itoh, "Planar ultra-wideband antennas in Ku- and K-band for pattern or polarization diversity applications," *IEEE Trans. Antennas Propag.*, vol. 60, no. 6, pp. 2886–2895, Jun. 2012.
- [189] J. H. Choi, J. S. Sun, and T. Itoh, "Frequency-scanning phased-array feed network based on composite right/left handed transmission lines," *IEEE Trans. Microw. Theory Techn.*, vol. 61, no. 8, pp. 3148–3157, Aug. 2013.
- [190] Y. D. Dong and T. Itoh, "Promising future of metamaterials," *IEEE Microw. Mag.*, vol. 13, no. 2, pp. 39–56, Mar.–Apr. 2012.

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