Steve Stearns, K6OIK

P.O. Box 4917, Mountain View, CA 94040-0917; **k6oik@arrl.net**

HOBBIES Software for Computational Electromagnetics

The latest in a series of software programs for electromagnetic analysis uses method-of-moments with higher-order basis functions.

Higher Order Basis Based Integral Equation Solver, called *HOBBIES*, is a computer program for the numerical analysis of general electromagnetic systems. *HOBBIES* capabilities include ac and RF systems. *HOBBIES* does not handle dc, electrostatic, or magnetostatic fields problems. *HOBBIES* is ideally suited for the modeling of antennas, arrays of antennas, coupled transmit and receive antennas, and scattering problems. The key features that distinguish *HOBBIES* from similar software tools lie in three areas: electromagnetic algorithms, the numerical algorithms for handling large matrices, and the computational architecture and implementation for efficient computation on small computers. As a result, *HOBBIES* can handle very large and complex models on a desktop or laptop computer, for which other software programs would require a supercomputer.

Versions

There are two versions of *HOBBIES* — Academic and Professional. The Academic version is a free download. Wiley provides a software registration code with the purchase of the *HOBBIES* software instruction book. The code can be used one time to obtain a software license that is locked to a user's disk drive. The Academic version handles problems of moderate complexity: 3,000 nodes, 15,000 unknowns, and 5,000 sample points for output responses.

The Professional version is sold by OHRN Enterprises. It costs several thousand dollars, far less than comparable professional software. The Professional version can handle large models. Both versions, Academic and Professional, have in-core and out-of-core solvers that use all of the available CPU cores. Small and medium problems run well on a laptop computer. Large models should be run on a multi-core desktop that has lots of memory and reliable fans as the fans may have to run for hours on large problems. The Professional version handles problems of large complexity: 70,000 unknowns in-core or 300,000 unknowns out-of-core, and 5,000 sample points for output responses.

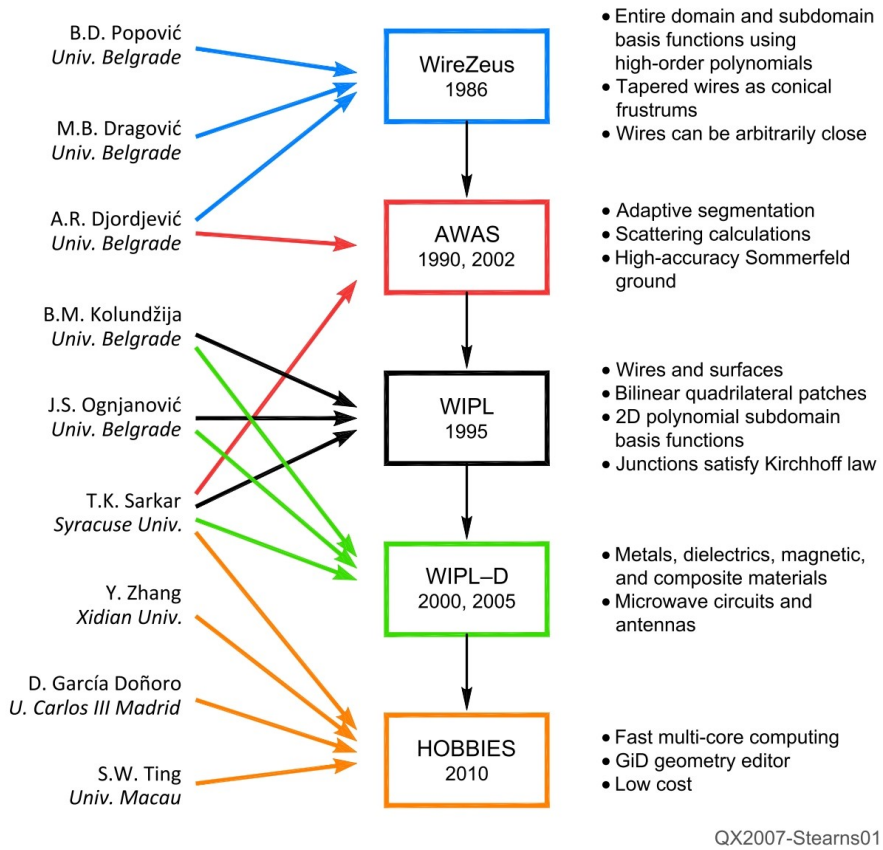


Figure 1 — Development history of *HOBBIES*.

The Shanghai Supercomputer Center reports obtaining stable convergent behavior when running *HOBBIES* with more than a million unknowns.

History

HOBBIES is the latest program in a series of software programs for electromagnetic analysis [1]. The programs in the series use method-of-moments with higher-order basis functions pioneered by Branko D. Popović in 1970 at University of Belgrade **[1]**, **[2]**. The programs in the series are *WireZeus* (1986), *AWAS* (1990), *AWAS 2.0* (2002) **[8]**, *WIPL* (1995), *WIPL-D* (2000), and *HOBBIES* (2010). Although *HOBBIES* relies on the work of researchers at several universities, the principal development was headed by T.K. Sarkar at Syracuse University and funded by the US government through government contracts to the university and OHRN Enterprises.

Figure 1 summarizes the development history. *WireZeus* **[4]** was a thin wire code roughly similar to *NEC* but which used polynomial basis functions on segments. *AWAS* provided for automatic setting of degree and segmentation, and added a numerically accurate Sommerfeld ground model. *WIPL* added surface modeling and meshing by quadrilateral patches. Patch shapes are bilinearly curved, not flat. *WIPL-D* added the capability to model objects made of homogeneous dielectric and magnetic materials. *HOBBIES* integrated the electromagnetic and computational software with the professional user interface *GiD*. The *GiD* interface allows for the easy import and export of standard geometry and mesh files, automatic meshing using user-defined rules, and post processing visualization graphics.

Capabilities

HOBBIES can analyze models made of wire and solid objects having arbitrary geometric shapes. Material properties are arbitrary and can be metals, dielectrics, magnetic materials or composite materials. Only materials that are linear, constant, homogeneous, and isotropic can be modeled. Materials that have a continuously varying or graded dielectric constant can be approximated by layers. So, for example, a graded-index Eaton lens or a planet with a molten iron core and an ionosphere are modeled by concentric spherical layers, each layer being homogeneous. *HOBBIES* does not have a Sommerfeld ground model. Ground is modeled in either of two ways. A complex reflection coefficient ground is provided. However, a reflection coefficient ground is not always accurate. A better way to model ground is as a dielectric surface. The ground is then meshed as part of an antenna or scatterer. This method allows the ground to have any shape; it need not be flat, horizontal, and smooth. The ground can be irregular. Topographic map data can be imported and used as ground if desired.

HOBBIES and *WIPL-D* both have thin wire codes and surface codes. The thin wire codes derive from *AWAS* and are asymptotically convergent in the limit of small spacing between wires. Consequently open wire transmission lines can be modeled physically. This is an improvement over codes like *NEC* which become inaccurate if wires are close to other wires or the ground. Coaxial structures can likewise be modeled and with dielectric fill.

HOBBIES allows one to define curved wires by parametric equations. Curved surfaces can also be defined by parametric equations. Moreover, the equations can be expressed in terms of variables, called Symbols. This allows the shape of a wire or surface to be tailored or optimized by varying the symbols of the defining equations.

HOBBIES handles both antenna and scattering calculations. It allows excitation by one or several source generators or by one or several incident plane waves. Source generators can be delta gap or magnetic frill types. The author's tests show the shunt capacitance error of the delta gap source model is smaller in *HOBBIES* than in *FEKO* or *NEC2/4*. Consequently resonant frequencies and characteristic modes are more accurately found.

The optimizer in *HOBBIES* offers three optimization engines: *Nelder-Mead*, *Gradient Descent*, and *Particle Swarm*. If good initial values for symbols are given, *Nelder-Mead* produces excellent results. If good initial conditions are unknown, *Particle Swarm* is recommended.

HOBBIES provides graphical output and numerical data. Output quantities computed by *HOBBIES* are currents, port parameters, far field patterns, and fields at finite locations. Port parameters are computed as *Y*, *Z*, and *S* matrix parameters. All computed output data are stored in text files and can be read or copied for external conversion to other file formats such as Touchstone *.sNp*. Fields are electric field **E**, magnetic field **H**, and Poynting vector **S**. Real and imaginary parts are computed and stored for each component of a vector. Graphs can additionally display magnitude and phase. *HOBBIES* can also make full-wave color videos of fields, which show how waves form and move through space.

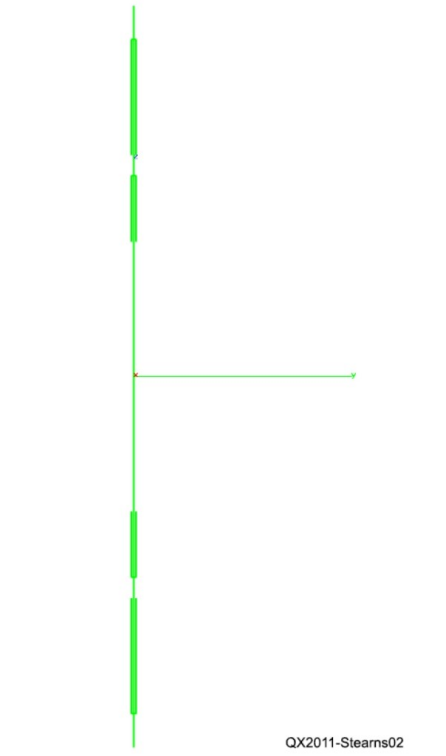


Figure 2 — A triband Extended Double Zepp (EDZ) antenna model.

Figure 3 — Optimally curved shape for a very high gain Landstorfer-type antenna.

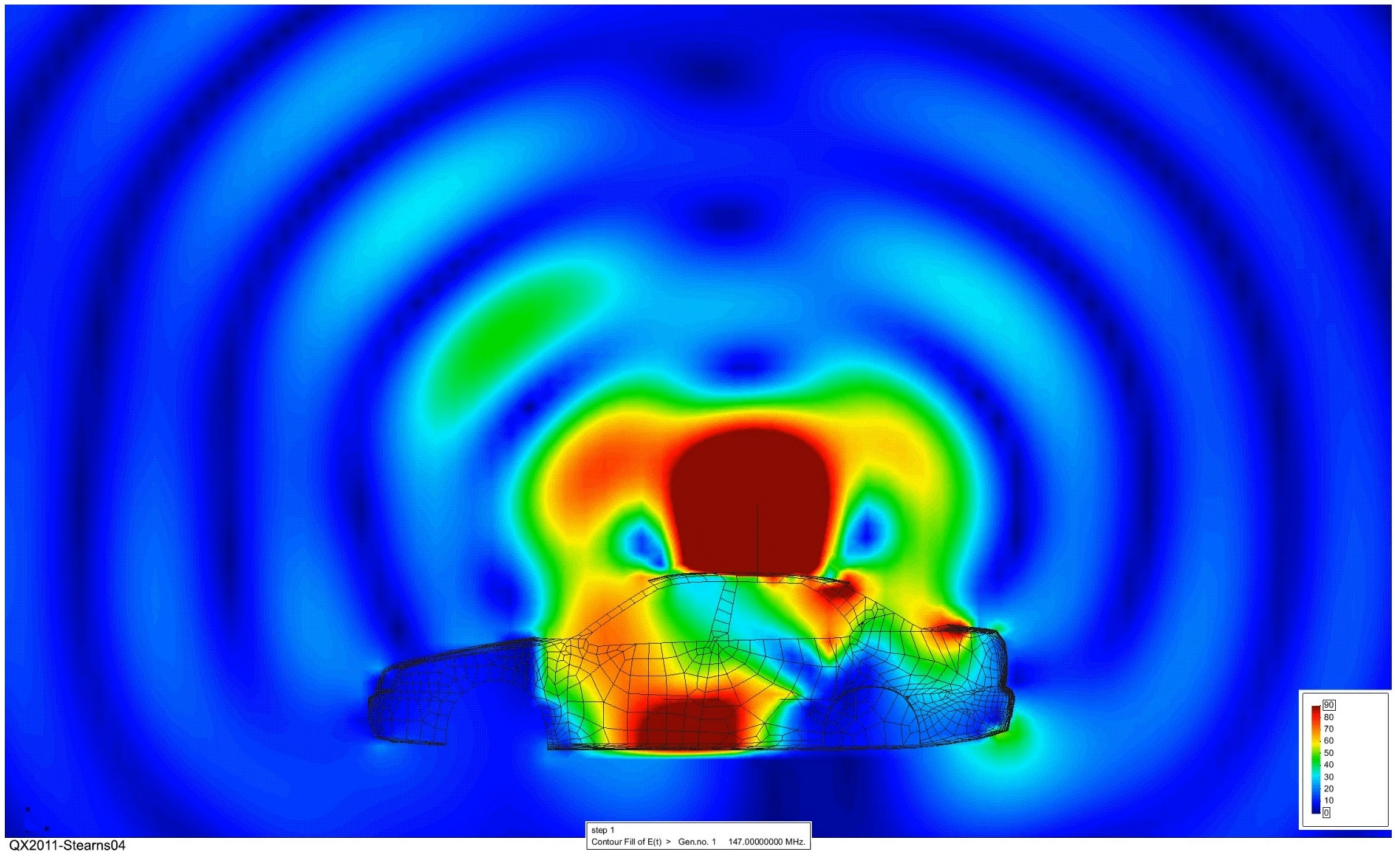


Figure 4 — Electric field inside an empty car at 147 MHz.

Examples

Five examples of models set up and analyzed in *HOBBIES* are shown below. It should be noted that these examples cannot be readily analyzed by *EZNEC* using either *NEC2* or *NEC4*. Full explanations and additional examples are in the author's tutorial presentations on computational electromagnetics and antenna modeling which are given annually at ARRL Pacificon **[12]**, **[13]**. Starting in 2019, a half-day short course is offered on advanced antenna modeling **[14]**.

Example 1

Figure 2 shows a model of a 2 meter, 1.25 meter, and 70 centimeter triband Extended Double Zepp (EDZ) with close-spaced transmission line cage traps. *HOBBIES* found the optimum dimensions of a slim vertical EDZ having gains close to 6 dBi on all bands. It can be re-optimized for conversion to coaxial end-feed.

Example 2

Figure 3 shows curved elements. *HOBBIES* found the optimum shape for a very high gain Landstorfer-type antenna.

Example 3

Figure 4 shows the fields inside a car with a monopole on roof radiating 75 W. *HOBBIES* was used by the author to confirm an article by KI6BDR in *QST*, October 2016. An independent calculation by AE7PD was published in RSGB *RadCom*, April 2020.

Example 4

Figure 5 shows a 160 m monopole with elevated radials surrounded by four short

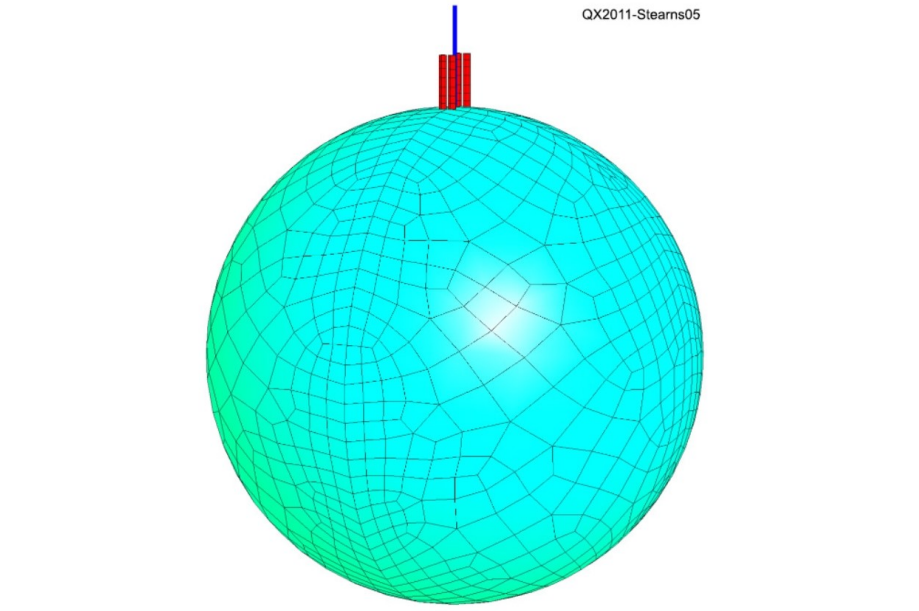


Figure 5 — Model of 160 m vertical antenna and trees on a dielectric planetoid.

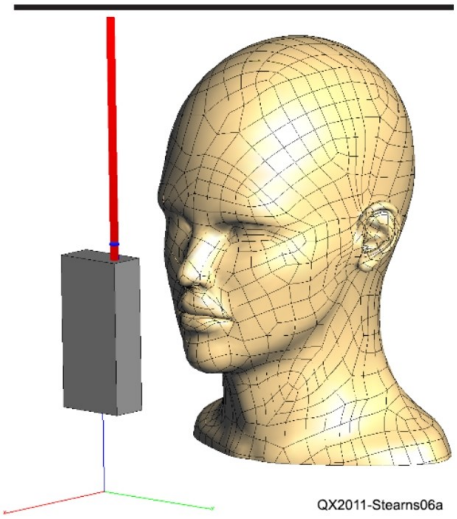


Figure 6A — Model of a head and hand-held radio.

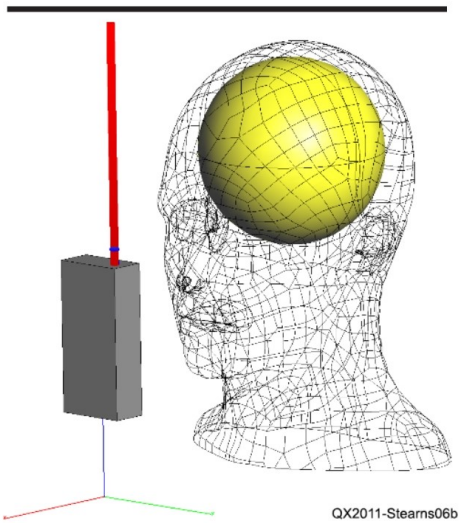


Figure 6B — Model of a transparent head showing a spherical brain.

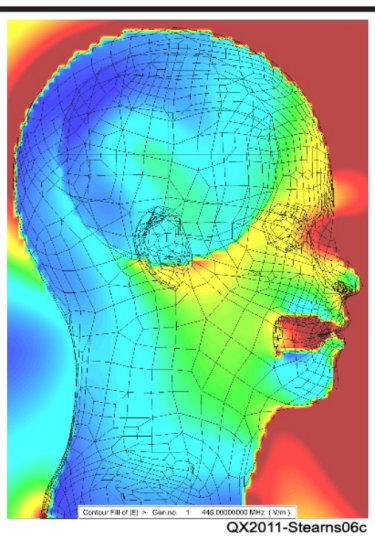


Figure 6C — Electric field strength in the central plane through the head.

trees on a spherical dielectric planetoid having an iron core. *HOBBIES* showed that a Sommerfeld infinite, flat-earth model gives different, inaccurate far field patterns.

Example 5

Figure 6A shows a human head with a handheld radio. **Figure 6B** shows a sphere brain with a handheld radio. **Figure 6C** shows the electric field strength in central plane through the head inside the brain computed by *HOBBIES*. Color scale (gray scale) can be adjusted or recalibrated to give specific absorption rate (SAR) directly for a specified tissue type.

Learning *HOBBIES*

A new user may find *HOBBIES* intimidating but no more so than other programs. *HOBBIES* is actually fun to learn. A new user should have two documents — the *HOBBIES* instruction book **[11]** and the *GiD* version 9 or 10 User Manual, a free download from the *GiD* support manual archive at **[16]**. The electromagnetic theory of the algorithms in *HOBBIES* is fully explained in **[3]** – **[7]** and summarized in **[9]** and **[11]**. A good way to learn *HOBBIES* is by watching the tutorial videos offered at *HOBBIES* support **[15]**, namely: (1) Dipole antenna; (2) Linear phased array of dipoles; (3) Square plate scatterer; (4) Cube scatterer; (5) Bowtie antenna; (6) Inhomogeneous dielectric cube scatterer; (7) Dielectric spherical radome; (8) Optimizer demo – optimizing the forward gain of a horn antenna; (9) Surface meshing.

If one's prior modeling background is *EZNEC*, a significant hurdle is to learn how to make and edit geometries, work with CAD files, convert a geometry to a mesh (meshing), and convert a mesh to a geometry. People who are familiar with 3D printing (artists, designers, makers, and mechanical engineers) will find such matters straightforward. A recommended adjunct to *HOBBIES* is the free software *FreeCAD* **[17]**. It is useful for editing geometry files and exporting them in formats that *HOBBIES* can import.

In addition to learning how to work with geometries, another useful skill is learning how to access computed data. *HOBBIES Post Processor* presents outputs as graphs. There are no front-panel controls or menu items for accessing computed data. All computed data exists in text files that are located in the *Post* folder inside a model's *.gid* project folder. The name extensions of the text files indicate what kind of data the file contains. There are four file types of interest identified by their file name extensions.

- *.ad1* files contain port admittance, impedance, and *S* parameter data.
- *.nf1* files contain field data for **E**, **H**, and the Poynting field vector in Cartesian component form.
- *.ra1* files contain far field radiation pattern data in spherical component form.
- *.cu1* files contain current data.

The user can open these files and copy and paste from them. Since data is arranged in tabular format, the files are easy to open in Microsoft Word and extract specific data by using Word's "text-to-table" and "table-to-text" commands.

Obtaining and Installing *HOBBIES*

Academic *HOBBIES* is obtained by downloading from the *HOBBIES* support web site **[15]**. A license is required to run the program. Every new copy of the instruction book **[11]** has a sealed envelope inside the back cover that contains a registration code. This code can be used one time only to obtain a license through the *HOBBIES* support web site. The online price of the book varies widely among sellers. When buying the book online the purchaser should confirm that the registration code is included and unused. It is recommended to buy only new copies from reputable sellers.

Two caveats are (1) *Academic HOBBIES* is supported by academics and only part time. The web site has a history of disappearing and reappearing. While the reasons are unknown, some theories are the server moved from one university to another and domain name registration expired and was later renewed. (2) It has been reported that Wiley did not put registration code envelopes in recent book runs. Purchasers report being able to get missing registration codes by complaining to Wiley Customer Service/Support through one or more levels of supervisors.

Professional HOBBIES is available for purchase from OHRN Enterprises. Contact Professor Tapan K. Sarkar at Syracuse University to purchase.

A last caveat is that *HOBBIES* is young software. As with any complex software, bugs are occasionally found as when commands or features don't work as expected. The program may halt, hang, or

crash on occasion. It is recommended to make a backup copy of the installation file and a read-only copy of the license files. This enables one to uninstall and reinstall the program if necessary. If the program halts or hangs, it might be a memory or a Windows problem. Use Windows Task Manager to stop the program. Then restart it. Bugs should be reported to *HOBBIES* support, which may reply asking for the project files that elicit the bug in order to diagnose and provide a patch.

In summary, *HOBBIES* is an excellent tool, comparable to *FEKO* and *WIPL-D*, and far more capable than software based on *NEC*, *MiniNEC*, or *Matlab*. *HOBBIES* handles a larger class of problems. It is inexpensive. It runs on ordinary Windows laptop and desktop computers. However it does require patience when issues are encountered, and it is not recommended for neophytes who are learning antenna theory and modeling for the first time.

Steve Stearns, K6OIK, started in ham radio while in high school at the height of the Heathkit era. He holds an FCC Amateur Extra and a commercial General Radio Operator License with Ship Radar Endorsement. He previously held Novice, Technician, and First Class Radiotelephone Licenses. He studied electrical engineering at California State University Fullerton, the University of Southern California, and Stanford, specializing in electromagnetics, communication engineering and signal processing. Steve was a Technical Fellow of Northrop Grumman Corporation before retirement. He worked at Northrop Grumman's Electromagnetic Systems Laboratory in San Jose, California, where he led the development of advanced communication signal processing systems, circuits, antennas, and electromagnetic devices. Steve is Vice-President of the Foothills Amateur Radio Society, and served previously as Assistant Director of ARRL Pacific Division under Jim Maxwell, W6CF. He has over 80 professional publications and ten patents. Steve has received numerous awards for professional and community volunteer activities.

References and Bibliography

[1] B. D. Popović, "Polynomial Approximation of Current Along Thin Symmetrical Cylindrical Dipoles," *Proc IEE*, vol. 117, no. 5, pp. 873-878, May 1970.

[2] B. D. Popović, "On Polynomial Approximation of Current Along Thin Asymmetrical Cylindrical Dipoles," *IEEE Trans. Antennas and Propagation*, vol. 19, no. 1, pp. 117-120, Jan. 1971.

[3] B. D. Popović, M. B. Dragćonović, and A. R. Djordjević, *Analysis and Synthesis of Wire Antennas*, Wiley, 1982.

[4] B. D. Popović, *CAD of Wire Antennas and Related Radiating Structures*, Wiley, 1991.

[5] B. D. Popović and B.M. Kolundžija, *Analysis of Metallic Antennas and Scatterers*, IET, 1994.

[6] B. M. Kolundžija, *WIPL: Electromagnetic Modeling of Composite Wire and Plate Structures*, Artech House, 1995.

[7] B. M. Kolundžija and A. R. Djordjević, *Electromagnetic Modeling of Composite Metallic and Dielectric Structures*, Artech House, 2002.

[8] A. R. Djordjević, et al., *AWAS for Windows Version 2.0*, 2nd Ed., Artech House 2002.

[9] B. M. Kolundžija, et al., *WIPL-D Microwave: Circuit and 3D EM Simulation for RF & Microwave Applications*, Artech House 2006.

[10] D. García-Doñoro, Y. Zhang, W. Zhao, T. K. Sarkar, L. E. García-Castillo, and M. Salazar-Palma, "HOBBIES: A New Electromagnetic Simulator," *IEEE Int. Symp. Antennas and Propagation*, Toronto, Ontario, Canada, July 11-17, 2010.

[11] Y. Zhang, et al., *Higher Order Basis Based Integral Equation Solver* [HOBBIES], Wiley, 2012.

[12] S. D. Stearns, "Antenna Modeling for Radio Amateurs, Revised and Expanded," presented at ARRL Pacificon, San Ramon, CA, October 20-22, 2017. Slides archived at **www.fars.k6ya.org/docs/k6oik**.

[13] S. D. Stearns, "Antennas: The Story from Physics to Computational Electromagnetics," presented at ARRL Pacificon Antenna Seminar, San Ramon, CA, Oct. 19-21, 2018. Slides archived at **www.fars.k6ya.org/docs/k6oik**.

[14] S. D. Stearns, *Antenna Modeling Seminar*, half-day short course, ARRL Pacificon, San Ramon, CA, Oct. 18-20, 2019.

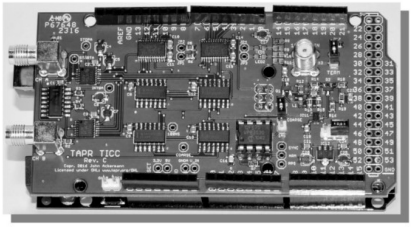
[15] HOBBIES web site (not always reliable) **www.em-hobbies.com**.

[16] GiD web site **https://www.gidhome.com**.

[17] FreeCAD web site **https://www.freecadweb.org**.

TAPR has 20M, 30M and 40M WSPR TX Shields for the Raspberry Pi. Set up your own HF WSPR beacon transmitter and monitor propagation from your station on the wsprnet.org web site. The TAPR WSPR shields turn virtually any Raspberry Pi computer board into a QRP beacon transmitter. Compatible with versions 1, 2, 3 and even the Raspberry Pi Zero! Choose a band or three and join in the fun!

TAPR is a non-profit amateur radio organization that develops new communications technology, provides useful/affordable hardware, and promotes the advancement of the amateur art through publications, meetings, and standards. Membership includes an e-subscription to the TAPR Packet Status Register quarterly newsletter, which provides up-to-date news and user/technical information. Annual membership costs $30 worldwide. Visit **www.tapr.org** for more information.



TICC

The **TICC** is a two channel time-stamping counter that can time events with 60 picosecond resolution. Think of the best stopwatch you've ever seen and make it a hundred million times better, and you can imagine how the TICC might be used. It can output the timestamps from each channel directly, or it can operate as a time interval counter started by a signal on one channel and stopped by a signal on the other. The TICC works with an Arduino Mega 2560 processor board and open source software. It is currently available from TAPR as an assembled and tested board with Arduino processor board and software included.

TAPR

1 Glen Ave., Wolcott, CT 06716-1442
Office: (972) 413-8277 • e-mail: taproffice@tapr.org
Internet: www.tapr.org • Non-Profit Research and Development Corporation