Classification of Intentional Electromagnetic Interference (IEMI)

D.V. Giri, Senior Member IEEE, and F. M. Tesche, Fellow IEEE

Abstract—One can classify potential IEMI threat environments into four categories, based on frequency coverage. Yet another way of categorizing IEMI environments is based on the level of sophistication of the underlying technologies involved in producing the EM environment, as low, medium and high-tech systems. This paper will examine the merits of classifying IEMI and provide examples of HPEM generators that employ current and emerging technologies, for each category of the classification.

Index Terms—Intentional EMI, bandratio, High-Power Electromagnetics (HPEM), threat environments

I. INTRODUCTION

In the modern context, we are increasing our reliance on the technological advancements of computer and electronic systems. Diverse activities of civilized societies, such as, civil defense, air-traffic safety and control, police, fire departments, ambulances, hospitals, communication and commerce are becoming more and more dependent on advanced technologies. While this dependence on technology increases the level and quality of service that can be offered to the general public, this sophistication comes with the price of enhanced vulnerability, posing a threat to civilized societies.

It is now well established that sufficiently intense electromagnetic signals in the approximate frequency range of 200 MHz to 5 GHz are known to cause electronic damage in many systems. Such an intentional EMI environment can be:

- a single pulse with many cycles of a single frequency (an intense narrowband signal that may have some frequency agility),
- a burst containing many pulses, with each pulse containing many cycles of a single frequency,
- an ultra-wideband pulse (spectral content from 100s of MHz to several GHz),
- a burst of many ultra-wideband transient pulses, which could be radiated or conducted.

One can classify such potential EMI threats into four categories, based on frequency coverage, as narrowband, moderateband, ultra-moderate and hyperbands. One could consider a bandratio \( br = \left( \frac{f_h}{f_l} \right) \), and using the inherent features of \( br \) in a manner consistent with the emerging technologies, we propose the following definitions for bandwidth classification [1].

<table>
<thead>
<tr>
<th>Band Type</th>
<th>Percent Bandwidth ( pbw )</th>
<th>Bandratio ( br )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narrow or hypoband</td>
<td>(&lt;1%)</td>
<td>(&lt;1.01)</td>
</tr>
<tr>
<td>Moderate or mesoband</td>
<td>(1% &lt; pbw \leq 100%)</td>
<td>(1.01 &lt; br \leq 3)</td>
</tr>
<tr>
<td>Ultra-moderate or sub-hyperband</td>
<td>(100% &lt; pbw &lt; 163.4%)</td>
<td>(3 &lt; br \leq 10)</td>
</tr>
<tr>
<td>Hyperband</td>
<td>(163.4% &lt; pbw &lt; 200%)</td>
<td>(br \geq 10)</td>
</tr>
</tbody>
</table>

Typically, the low and high frequency limits are 3 dB down from a flat spectrum. Not all spectra are “flat”; consequently, for waveforms with uneven spectra, the criterion for the finding \( f_l \) and \( f_h \) could be based on the energy content in a certain spectral interval [2], as follows. One can find \( \Delta f(f_h, f_l) = f_h - f_l \) such that \( \Delta f(f_h, f_l) \) becomes minimal. When written using the norm nomenclature this is expresses as

\[
\frac{\| \tilde{V}(j\omega) \|_{f_h, f_l}^{f_h, f_l}}{\| \tilde{V}(j\omega) \|_{f_h, f_l}^{f_h, f_l}} = 0.9
\]

This definition insures that 90% of the overall energy is contained in the interval \( (f_l, f_h) \).

Furthermore, for spectra with large dc content (e.g., E-1 portion of Nuclear Electromagnetic pulse or NEMP), one just
has to calculate $f_n$, determine the decades (bandwidth decades $brd$) from 1 Hz to $f_n$ Hz and calculate $br$ using $br = 10^{brd}$.

In other words, we stipulate the lower limit to be 1 Hz, if the spectrum has large dc content.

Yet another way of categorizing IEMI environments is based on the level of sophistication of the underlying technologies involved in producing the EM environment, as low, medium and high-tech systems. The low-tech systems are characterized by: i) marginal performance, ii) minimal technical capabilities and iii) easily assembled and deployed while hiding behind dielectric walls in trucks and similar vehicles. In contrast, medium-tech systems require the skills of a qualified electrical engineer and relatively more sophisticated components such as a commercially available radar system that can be modified to become a weapon system. More sophisticated high-tech and high-power electromagnetic (HEMP) systems would require specialized and sophisticated technologies and perhaps even specifically tuned to cause severe damage to a specific target.

Illustrative examples of potential HPEM sources in different categories are described in this paper.

II. HPEM ENVIRONMENTS AND TYPES OF EFFECTS

Generally speaking military assets and a few civilian systems (e.g., nuclear power plants, communications facilities, etc.) in some nations are protected against the damaging effects of High-Altitude Electromagnetic Pulse (HEMP) [3, 4]. The emerging HPEM threat environments are compared qualitatively with the HEMP waveform in figure 1. The magnitude of the electric field spectrum is plotted on the y-axis in figure 1. Typical natural lightning waveform is also included and it is noted that the lightning spectrum can extend to 20 MHz for return strokes at a range of approx. 50 km [5].

![Fig. 1. Several types of HPEM environments compared with the HEMP waveform](image)

An intentional electromagnetic environment is a man-made threat specifically designed to cause interference or damage to electrical and electronic components or systems. For the purpose of illustrating the consequences of such environments, one may choose a civil aviation example of an aircraft landing at a civilian airport [6].

A. Noise (front door)

Sensitive receivers in civilian electronic systems are designed to operate with E-field levels as low as several $\mu$V/m, within a narrowly tuned receiver bandwidth. It is very easy to overpower such signals by a decade or more of field strength. The user of the electronic device/equipment merely experiences noise in the receiver that lasts as long as the disturbing environment.

Consequences of this interference may not always be critical. In the worst-case scenario, the pilot aborts landing and makes another try or goes to an alternate airport.

B. False information (front door)

Once again with a decade or more E-field strength above the signal level, the intentional electromagnetic signal may be designed to feed false information to the receiver.

Consequences here may be critical, since the aircraft can land somewhere other than the runway.

C. Transient upset (back door)

It is noted that one requires several volts of induced signals to affect the logic state of an electronic component. At a frequency of ~ 1 GHz, an effective coupling height of 0.1m is typical for unhardened/open systems. This implies 10s to 100s of V/m of tuned narrowband environment is required to cause an effect. The pulse width is assumed to be such that the quality factor Q of the threat environment is greater than the victim system Q [7 - 9]. At the nominal frequency of 1 GHz, approximately 100 cycles or 100ns pulse duration should be sufficient.

Consequences of this interference depend on system design for recovery and repetition of threat environment.

D. Permanent damage (back door)

For permanent damage to occur, semiconductor junctions must be exposed to over-voltages that result in breakdown. This phenomenon means that the bias on the junction is also a factor. At a nominal frequency of 1 GHz, this requires several kV/m [10] incident electric field strengths.

III. CLASSIFICATION BASED ON FREQUENCY COVERAGE

The present interest is the potential high-power electromagnetic threat to electronic systems and facilities. It is now well established that sufficiently intense electromagnetic signals in the frequency range of 200 MHz to 5 GHz may cause electronic damage in many systems. HPEM generators are effective in this frequency range for the following reasons.

- There are deliberate antennas operating in this frequency range, which provide a path into the system (front door coupling paths)
Typical apertures, slots, holes and hatch openings have their resonance in this frequency range (inadvertent or back-door coupling paths)

- Typical rivet spacing at the junction of two metallic surfaces at the skin level are about a quarter to a full wavelength in this frequency range (1 to 2 GHz)
- Physical dimensions of circuit boxes are themselves resonant in this frequency range (1 to 2 GHz)
- The interior coupling paths (e.g., transmission lines, cables at a height above the ground plane), are roughly a quarter to a full wavelength in this frequency range (1 to 2 GHz)

A. General attributes of HPEM or IEMI

In the context of electronics systems and facilities, various elements of electromagnetic threat environments include:

- Source characterization
- Feed and antenna system
- Propagation distances and losses
- Coupling to the facility exterior
- Transfer function to the system interior

The source is characterized by its output power, frequency, frequency agility, duration and repetition rates for pulsed sources and burst lengths. Feed and antenna systems in this frequency range of (200 MHz to 5 GHz) consist of electromagnetic horns and reflectors.

- Frequency range 200 MHz to 5 GHz
- Wavelength range 6 cm to 150 cm
- CW source power (rms) 1 kW (microwave oven) to 10 MW (radar tubes)
- CW source power (peak) P = 2 kW to 20 MW
- Antenna aperture area A = up to 10 m² (a practical sized antenna that can be truck mounted and be driven under overpasses and on bridges)

Peak e-field on radiating aperture \( E_0 = \sqrt{PZ/A} \)

Peak radiated e-field \( E_r = E_o A/(\pi d) \)

The aperture and the “far voltage” for the assumed power levels are shown in Table 2. CW sources that can produce average power levels in the range of 1 kW (continuous) to 10 MW (pulsed) are readily available today, and the estimates of Table 2 can be easily produced. We can now estimate the electric field levels as a function of frequency and range with the above commercial sources. This leads to the results in Table 3. The CW results in Table 3 indicate that with the commercially available sources that have rms outputs ranging from 1 kW to 10 MW, it is indeed possible to produce greater than 100 V/m signals at kilometer distances, with modest sized antennas. The frequency range in the L-band is likely to cause more electronic damage than higher bands (10 GHz radar for example) [11].

### Table 2

<table>
<thead>
<tr>
<th>Qty.</th>
<th>Peak Power = 2 kW</th>
<th>Peak Power = 20 MW</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5 GHz</td>
<td>1 GHz</td>
</tr>
<tr>
<td>aperture field ( E_0 )</td>
<td>274 V/m</td>
<td>274 V/m</td>
</tr>
<tr>
<td>far voltage ( E_r )</td>
<td>4.57 kV</td>
<td>9.13 kV</td>
</tr>
</tbody>
</table>

### Table 3

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Range</th>
<th>Antenna aperture of 10 m² and Output power of 2 kW</th>
<th>Antenna aperture of 10 m² and Output power of 20 MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 MHz</td>
<td>300m</td>
<td>15.23 V/m</td>
<td>1.52 kV/m</td>
</tr>
<tr>
<td></td>
<td>1 km</td>
<td>4.57 V/m</td>
<td>457 V/m</td>
</tr>
<tr>
<td>1 GHz</td>
<td>300 m</td>
<td>30.43 V/m</td>
<td>3.04 kV/m</td>
</tr>
<tr>
<td></td>
<td>1 km</td>
<td>9.13 V/m</td>
<td>913 V/m</td>
</tr>
<tr>
<td>2 GHz</td>
<td>300 m</td>
<td>60.90 V/m</td>
<td>6.09 kV/m</td>
</tr>
<tr>
<td></td>
<td>1 km</td>
<td>18.27 V/m</td>
<td>1.83 kV/m</td>
</tr>
<tr>
<td>3 GHz</td>
<td>300 m</td>
<td>91.33 V/m</td>
<td>9.13 kV/m</td>
</tr>
<tr>
<td></td>
<td>1 km</td>
<td>27.40 V/m</td>
<td>2.74 kV/m</td>
</tr>
</tbody>
</table>

In the context of hyperband HPEM systems, TEM horns and reflectors fed by TEM transmission lines are established as efficient radiators. For example, half-cycle and single cycle sine wave generators at 1 GHz, with amplitudes of 100 kV (peak to peak) are realistic and practical sources. One could consider a single TEM horn antenna for radiating such a pulse. Preliminary calculation of the TEM horn radiation indicates an \((rE_r / V)\) of about 0.5. This antenna is not necessarily an optimal design. This means one could produce an impulse-like signal with amplitude of about 50 V/m at 1 km with a hyper bandwidth.

In summary, the parameter space for a hyper-bandwidth system from commercial components included the following: source waveform half-cycle or full-cycle sine wave
amplitude 100 kV peak-to-peak for full cycle, 
50 kV for the half cycle
“frequency” 1 GHz (nominal)
antenna type a TEM horn (readily available)
antenna volume 30 cm x 30 cm x 30 cm
(1 wavelength in each dimension)
peak field at 1 km distance ~ 50 V/m (time domain peak
bandwidth ~ 100 MHz to a few GHz)

As in the case of narrowband sources, it is possible to array
the sources and antennas. The time domain field at early times
is additive. For example, a 3 m x 3 m array could contain about
150 elements and the peak signal can reach up to 7.5 kV/m at a
distance of 1 km.

A. HPM waveform characteristics: Phaser (hypo or
narrowband)

The term "Phaser" stands for Pulsed High-Amplitude
Sinusoidal Electromagnetic Radiation. A progression of
potential Phaser designs is referred to as Mark N Phasers and
is defined by source powers of $10^N$ GW [12]. Thus a Mark 0
Phaser has a power out from the source of 1 GW. The power
out of the source is typically referenced to the lowest order
waveguide mode which can be coupled into a pyramidal horn
antenna as described in detail in [12]. A good example is a
relativistic magnetron source that is commercially available
[13] with the following capabilities.

Frequency = 1.1 GHz
Peak power = 1.8 GW (average power = 0.9 GW)
Pulse width = 60 ns (contains 66 cycles)

This commercial source can easily be modified to produce
an average power of 1 GW, with slightly increased pulse
duration of 100 ns to contain greater than 100 cycles of L-band
sinusoidal signal. This makes the quality factor $Q = \frac{\pi}{\delta}$ $N = 314$
and $pbw = \frac{100}{Q} = 0.32$, $br = 1.0032$. With an antenna of
about 10 m aperture area, it is estimated that such a system
can easily produce fields of 2.3 kV/m at 3 km and 700 V/m at
10 km. These generator systems can also be truck-mounted
and can come in close proximity to civilian electronics systems
and facilities, producing much higher field levels.

Several narrowband generator systems in the frequency
range of 0.7 GHz to 3 GHz exist. Examples include:

1) The Swedish Microwave Test facility, Linkoping,
Sweden.
2) The Orion system in U.K., which uses relativistic
magnetrons and horn-fed reflector antennas (figure 2).
3) Super Reltron based system in CEG, Gramat, France,
called the Hyperion.
4) Super Reltron based system at WIS, Munster,
Germany.

Fig. 2. The ORION narrow or hypoband HPM system
[14].

It is noted that these systems are used in studying the
vulnerabilities of electronic systems. However, some smaller-
scale versions of such systems could be used for destructive
purposes, if acquired by organizations/groups intent upon
harming civilized societies. Therein lies the potential threat in
the present context of civilian electronics systems and
facilities.

B. Dispatcher (moderate or mesoband)

The term "Dispatcher" stands for Damped Intensive
Sinusoidal Pulsed Antenna, Thereby Creating Highly
Energetic Radiation. While the Phaser is a narrowband device
in which about 100 cycles of a single frequency radiation are
produced in each pulse, Baum [15, 16] has described certain
systems that integrate an oscillator into the antenna system.

Examples are: (a) a low-impedance quarter wave
transmission line oscillator feeding a high-impedance antenna,
and (b) a low-impedance quarter wave transmission line
feeding a TEM fed reflector. The transmission line oscillator
consists of a quarter wave section of a transmission line
(perhaps in oil or high-pressure gas medium for voltage stand
off), that is charged by a high voltage source and a self-
breaking switch across the transmission line. When the switch
closes, a pulsed signal is fed into the antenna connected to this
transmission line that radiates an HPEM signal. As an example,
500 MHz corresponds to a quarter wavelength in transformer oil of 10 cm, which is very compact. The charge
voltages can be in the range of 100s of kV. The half wave
section doubles the length for a given frequency and thus
increases the stored energy. This is included here as an
emerging system that may be used in creating HPEM
environments on electronic systems such as the civilian
electronics systems and facilities.

IV. EXAMPLES OF IEMI BASED ON TECHNOLOGY
SOPHISTICATION

As was pointed out earlier, it is possible to classify the
emerging HPEM or IEMI systems is based on the technical
sophistication level in assembling and deploying such systems.
A. Low-tech generator systems

- Require minimal technical capabilities
- Marginal component performance
- Easily assembled and deployed while hiding behind dielectric truck walls or in similar vehicles.

A readily available CW microwave source in the S-band (2.45 GHz) is the magnetron in a microwave oven. Typical and readily available microwave ovens are rated at 800 W to 1,500 W of rms continuous microwave power. With 1,100 W of rms continuous microwave power at 2.45 GHz from a microwave oven, the peak electric field in the output waveguide is about 25 kV/m. Starting from such an e-field in the waveguide aperture, (rE_peak) factors obtainable are listed in Table 4.

### TABLE 4

<table>
<thead>
<tr>
<th>Antenna type</th>
<th>Power rms</th>
<th>Peak E-field in WR 340</th>
<th>rE_peak</th>
<th>E_peak _r = 300 m</th>
<th>E_peak _r = 1 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open-ended WR 340</td>
<td>1,100 W</td>
<td>25 kV/m</td>
<td>540 V</td>
<td>1.8 V/m</td>
<td>0.54 V/m</td>
</tr>
<tr>
<td>Pyramidal horn</td>
<td>1,100 W</td>
<td>25 kV/m</td>
<td>2200 V</td>
<td>7.3 V/m</td>
<td>2.2 V/m</td>
</tr>
<tr>
<td>Reflector antenna (1.8 m dia.)</td>
<td>1,100 W</td>
<td>25 kV/m</td>
<td>4680 V</td>
<td>15.6 V/m</td>
<td>4.7 V/m</td>
</tr>
</tbody>
</table>

This LPM system was used in exposing several test objects such as calculators, wrist-watches, electro-explosive devices, florescent tubes etc., with significant adverse effects (upset and burn-out).

B. Medium-tech generator systems

- Require the skills of a qualified electrical engineer
- Relatively more sophisticated components
- A commercially available radar system can be modified to become a weapon system.

Commercially available radars can be modified to become an HPEM system (narrowband or ultra wideband); examples of complete systems offered for sale by Radio Research Instruments Co., Inc. of Waterbury, CT are the AN/FPS-36, AN/FPS-71, AN/FPS-7, and AN/FPS-77.

The AN/FPS-71 search radar is chosen for illustrative purposes. Its salient parameters are:

- Aperture area _A_ = 93.5 m²
- Peak power output from the magnetron _P_ = 5 MW
- Average power from the magnetron _P_ _avg_ = 2.5 MW
- Frequency of operation _f_ = 1.285 GHz

L-band waveguide dimensions _a_ = longer dimension = 16.51 cm; _b_ = shorter dimension = 8.26 cm
Dominant modal impedance _Z_ 10 = 534 Ω
Focal length of the reflector _F_ = 2.5 m (assumed)
E-field on the aperture: _E_ _a_ = 630 kV/m (ab/λ) ~ 15 kV/m
Far field _rE_ product: _rE_ _f_ = _E_ _a_ (A/λ) ~ 6 MV

The (rE) estimated above implies that this commercially available system, which powered by a 5 MW magnetron source is capable of producing peak fields listed in Table 5.

### TABLE 5

<table>
<thead>
<tr>
<th>Range r</th>
<th>Peak e-field 93.5 m²</th>
<th>Peak e-field 9.35 m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 m</td>
<td>20 kV/m</td>
<td>6.3 kV/m</td>
</tr>
<tr>
<td>1 km</td>
<td>6 kV/m</td>
<td>1.9 kV/m</td>
</tr>
<tr>
<td>10 km</td>
<td>600 V/m</td>
<td>192 V/m</td>
</tr>
</tbody>
</table>

This commercial system has a large antenna aperture 93.5 m², which can easily be scaled down by a factor of 10, in which case the peak electric fields as shown in Table 5 decrease by a factor of √10. These levels are still significant with regard to system effects.

C. High-tech generator systems

- Require specialised and sophisticated technologies
- May be specifically tuned to cause severe damage to specific targets

Examples of high-tech HPEM generators are the Impulse Radiating Antennas (IRAs) [18-21]. An Impulse Radiating Antenna (IRA) with a diameter of 23 cm is shown in Figure 3.

---

**Fig. 3. Impulse Radiating Antenna (IRA) with a diameter of 23 cm**
This antenna has been used in the past with a HYPS pulser that has a voltage amplitude of 2.5 kV, risetime of 100 ps, FWHM of 2 ns and a prf of 500 Hz. The voltage pulse fed into the antenna is shown in figure 4 and the boresight temporal fields in figure 5. The above IRA is one of many that have been fabricated and tested, as listed in Table 6.

\[ V(t) = \frac{2.5}{t_{\text{rise}}} e^{-\frac{t}{t_{\text{FWHM}}}} \]

**Fig. 4. Pulser voltage (2.5 kV, 100 ps rise, FWHM 2 ns and 500 Hz prf)**

**TABLE 6**

<table>
<thead>
<tr>
<th>Name</th>
<th>Dia.</th>
<th>Pulser</th>
<th>peak</th>
<th>br</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFRL, KAFB</td>
<td>3.66m</td>
<td>120kV</td>
<td>1.3 MV</td>
<td>100</td>
</tr>
<tr>
<td>AFRL, KAFB</td>
<td>1.83m</td>
<td>150 kV</td>
<td>690 kV</td>
<td>50</td>
</tr>
<tr>
<td>Swiss IRA</td>
<td>1.8m</td>
<td>2.8 kV</td>
<td>10 kV</td>
<td>50</td>
</tr>
<tr>
<td>TNO IRA</td>
<td>0.9m</td>
<td>9 kV</td>
<td>34 kV</td>
<td>25</td>
</tr>
<tr>
<td>U. of Magdeburg, Germany</td>
<td>0.9m</td>
<td>9 kV</td>
<td>34 kV</td>
<td>25</td>
</tr>
</tbody>
</table>

**Fig. 5. Boresight temporal electric field of the 23 cm reflector IRA fed by the voltage pulse of figure 4**

V. SUMMARY

In this paper, we have described two ways of classifying intentional EMI. The classification schemes are based on: (a) the frequency of coverage or the bandwidth of the IEMI or HPEM signals and (b) the level of sophistication of the technologies required to produce the electromagnetic environment intended to cause damage to electronic systems. Illustrative example systems for each category are also presented in this paper.

It is emphasized that the IEMI signals can be both radiated and conducted and we have focussed on the radiated IEMI in this paper. Conducted HPEM environments are a potential threat to electronic equipment connected to power and communications lines [22-24]. In most modern buildings there is a personal computer on nearly every desk, and these computers are typically connected to the power supply and to a telephone cable or local area network (LAN). In the case of data communications, at the present time, most communications circuits that enter a building will pass through a router or switch before sending the data to individual equipment. This means that this interface electronic equipment is potentially vulnerable to HPEM conducted pulsed voltages.
and currents that may be transmitted into the building from the outside. For older installations, telephone lines enter a facility and are wired directly to individual telephones or computers inside. In this situation, internal electronic equipment could be damaged by externally injected HPEM pulsed voltages. Conducted IEMI signal can either be covertly injected on to power or signal cables are they may also be an induced environment due to a radiating IEMI source.

REFERENCES

D. V. Giri was born in India and is a naturalized U.S. citizen. He has undergraduate degrees in Physics and Mathematics and electrical engineering. After receiving his M. Engg. Degree from the Indian Institute of Science, he continued his graduate study at Harvard University receiving M.S. (Applied Mathematics, 1973) and Ph.D (Applied Physics, 1975). Dr. Giri has taught graduate and undergraduate courses in the Dept. of EECS, University of California, Berkeley campus and is presently a self-employed consultant as Pro-Tech, in Alamo, CA, doing R&D work for U.S. Government and Industry. From May 1978 to September 1984, he was a staff scientist at LuTech, Inc.

Prior to his association with LuTech, Inc., Dr. Giri was a Research Associate for the National Research Council at the Air Force Research Laboratory (AFRL), Kirtland AFB, NM. Dr. Giri is a senior member of the IEEE Society of Antennas and Propagation, a Charter member of the Electromagnetics Society, and Associate member of Commission B, URSI and member of Commission E, URSI. He has served on the editorial board of the Journal of Electromagnetics, published by Taylor and Francis. He has served as an Associate Editor for the IEEE Transactions on Electromagnetic Compatibility. The EMP Fellows Committee of Summa Foundation 1994 elected him to the grade of Fellow for his contribution to EMP simulator design HPM antenna design. He has published one book, one book chapter and over a hundred papers, reports etc.

Dr. Tesche, a consultant in the western North Carolina area, has been involved with many practical aspects of electromagnetics (EM) for over 30 years. Prior to forming his consulting practice, he was associated with a number of different firms, including E-Systems, Inc., LuTech, Inc. (a firm he co-founded in 1978 with T.K. Liu and D. V. Giri), Science Applications International Corp. (SAIC), the Dikewood Corp, and Northrop Corporate Laboratories. Presently, he is providing EM consulting services for a number of firms, including Pro-Tech, SAIC, Metatech Inc., and Amperion, Inc. In addition, Dr. Tesche is a Research Professor at Clemson University, where he is conducting research into the effects of HPEM fields on electrical systems and networks, and is developing a course on electromagnetic compatibility (EMC). He is also served as the permanent Technical Program Chairman for the biannual Zurich Symposium on EMC for the past 6 years.

Dr. Tesche is a Fellow of IEEE and is an EMP Fellow of the Summa Foundation. He has published widely in the open literature and has given many presentations at technical symposia. Additionally, he has received a number of awards for his publications and service to the IEEE.