Focusing an Arbitrary RF Pulse at a Distance using Time Reversal Techniques

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Focusing an Arbitrary RF Pulse at a Distance using Time Reversal Techniques

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Abstract—Time reversal technique is used to effectively send an arbitrary RF pulse to a localized region at a remote location. This approach uses the time-reversed impulse response between the target and the time-reversal mirror (TRM). We demonstrate this technique by extending the concept of the TRM to a reverberating box with an aperture to convolve an arbitrary RF pulse with the time-reversed impulse response before re-transmitting through the TRM port. Numerical simulation and measurements are conducted to demonstrate the technique. The results show that both temporal and spatial focusing take place at the target location. This approach could potentially be used for selective “beamforming” of a high power microwave system to effectively deliver an RF pulse of choice using the pre-stored (or obtained on the fly) impulse response for a given target location. Another application could be to focus RF energy at a targeted location in an enclosed system.

Index Terms—Time Reversal, Temporal and Spatial Focusing, Directed Energy, Beamforming.

I. INTRODUCTION

In an environment where time reversal (TR) symmetry of the wave equation exists in the propagation medium, a time reversal mirror (TRM) can be applied to temporally and spatially focus energy back to the source location by re-transmitting a time-reversed version of the response received through the TRM [1]. An ideal TRM has an infinite number of transceivers enclosing a lossless medium wherein a source is located, and captures the entire signal emitted from the source such that when the signal is time-reversed and re-transmitted into the medium, the source receives a perfectly reconstructed original signal (time-reversed). In practice there will always be some type of loss in the process - e.g. loss in the medium, and loss due to a finite number of transceivers in the TRM – that will degrade the quality of the reconstructed signal. Hence TRM works better in a rich scattering or closed reverberating environment where much of the excited energy from the source can be captured from different trajectories (multiple ray paths). Use of TR techniques was first introduced to focus acoustic waves [2], and more recently it was successfully applied to electromagnetic (EM) waves [3].

Since the first experimental demonstration, the use of electromagnetic TRM has been investigated in different application areas such as indoor wireless communications [3-5], tumor detection [6], and sensors [1,7,8]. More recently the potential use of the TRM for directed energy has been demonstrated using a reverberating box with an aperture to focus a broadband RF pulse at a distance outside the box [9].

In this paper, we present a technique to effectively focus an arbitrary RF pulse at a desired distant location. In this approach, the time-reversed impulse response between a given target location and the TRM is convolved with an arbitrary RF pulse, such that when transmitted through the TRM port, the RF pulse will focus at the target location. This method suggests that it requires only the impulse response between the ports to effectively apply the TRM with an arbitrary pulse at any frequency within the bandwidth of the impulse response. Using the TRM in a reverberating box with an aperture, we demonstrate the focusing of an RF pulse at a given target location using both numerical simulation and measurements.

The results show that the focusing takes place both in time and space, indicating that an RF pulse can be effectively delivered to the target location. This approach could potentially be used for selective “beamforming” of an HPM system to effectively deliver an RF pulse of choice using the

![Fig. 1. Potential applications of the TR technique for directed energy: a.) Use of different waveforms launched from the TRM to focused energy at different remote locations, and b.) Use of a waveform sent in through an aperture to reconstruct as a strong pulse at a key component inside the enclosure.](image-url)
II. APPROACH

A. TRM Process and TRM in a Leaky Box

The conventional TRM process involves four steps as shown in Fig. 2. First, Port 1 (source) transmits a pulsed waveform, \( x_1(t) \), and Port 2 (receiver, which consists of a single or multiple antenna elements) records the response, \( y(t) \), that is spread in time due to the signals following multiple ray paths. The recorded signal is then time-reversed and re-transmitted from Port 2. The time-reversed signal will then “backpropagate” to Port 1, focusing energy at the source location as depicted in Fig. 1a. Due to the spatial reciprocity of this problem, this approach could also be used to focus energy at a specific location in an enclosed system that has a finite number of entry points as shown in Fig. 1b.

Recently, Davy et al. have applied the TRM with an aperture backed by a reverberating box to focus a broadband RF pulse at a distance from the aperture outside the box [9]. As shown in Fig. 3, the focusing is made possible due to the reverberating box that allows much of the signal \( x_1(t) \) transmitted from Port 1 to enter through the aperture (spread in time due to multiple ray paths in the box) and to be captured at Port 2. When the TRM is applied and \( y(-t) \) is re-transmitted from Port 2, the aperture field distribution is reconstructed for the energy to be re-directed to Port 1. In [9], a parametric study was also performed regarding the peak power of the reconstructed pulse as a function of aperture size, pulsewidth (PW) and number of TRM antenna elements. In this paper, we study the spatial and temporal focusing of the time-reversed pulse using both numerical and experimental techniques.

B. Linear System Representation of TRM Process

Here we describe the TRM process in terms of a linear time-invariant system and the corresponding impulse response. Considering Ports 1 and 2 as the input and output ports of the system, respectively, the output signal, \( y(t) \), can be represented as

\[
y(t) = x_1(t) \otimes h_{21}(t) ,
\]

(1)

where \( x_1(t) \) is the input and \( h_{21}(t) \) is the impulse response of the system. The output recorded for a finite time duration of \( T \) is represented as

\[
y(t;T) = x_1(t) \otimes h_{21}(t;T) ,
\]

(2)

where \( h_{21}(t;T) \) is now an approximate impulse response between the two ports for a finite time duration of \( T \) and represents an approximation to the Green’s function that satisfies the wave equation. Due to the spatial reciprocity in the system, \( h_{12}(t) \) remains unchanged when the transport process reverses its direction (i.e., \( h_{21}(t) = h_{12}(t) \)). When \( y(t;T) \) is time-reversed and re-transmitted, the signal received at Port 1 is...
and the energy is compressed in time to peak around $t=T$, resulting in a pulse very close to a time reversed version of $x(t)$. Spatial focusing also occurs at Port 1, such that the amplitude peak of the signal observed at locations other than Port 1 decreases as a function of distance from Port 1, due to the variation of the impulse response function from $h_2(t)$. The spatial focal area is limited by diffraction theory and the minimum half-power focal area can be approximated by using the radiated pattern from a rectangular aperture [10], from which a one dimensional resolution is estimated as

$$\Delta x \cong 0.9 D \lambda / A,$$

where $D$, $\lambda$, and $A$ are the distance of the Port 1 from the aperture, wavelength, and a dimension (height or width) of the aperture, respectively.

If $x(t) = \delta(t)$, then Eqn.(3) becomes

$$x(t) = h_1(T-t;T) \otimes h_2(t),$$

where $x(t)$ now represent the autocorrelation function of $h_2(t)$, which peaks at $t=T$. For locations other than Port 1, $x(t)$ simply becomes a cross-correlation function that has a relatively lower peak at $t=T$, since the impulse response of the re-transmission channel differs from the original impulse response. This implies that the TR process can be viewed as a temporal and spatial correlator [2].

C. Sending an Arbitrary Pulse

Now we introduce an arbitrary RF pulse, $x_p(t)$. When $x_p(t)$ is convolved with the time-reversed impulse response and transmitted through Port 2, the representation of $x_p(t)$ as in Eqn. (5) is modified to

$$x(t) = x_p(t) \otimes h_1(T-t;T) \otimes h_2(t).$$

In Eqn.(6), due to temporal compression in the autocorrelation term, $h_1(T-t;T) \otimes h_2(t)$, the original pulse shape of $x_p(t)$ is preserved and peaks around $t=T$. The essence of this approach lies in the time-reversal impulse response, which is capable of undoing the phase changes and distortions at all frequencies. Therefore, when convolved with an arbitrary RF pulse and transmitted from Port 2, the RF pulse will be effectively delivered to Port 1 in its original pulse shape. Spatial focusing of the peak power should also take place at Port 1 in the same manner as previously mentioned. Fig. 3 shows a modified illustration of the TRM in a leaky box using the time-reversal impulse response concept. From a practical perspective, where the “impulse response” has a finite bandwidth due to the PW of the excitation pulse, as well as the bandwidth of transmit and receive system (i.e. ports, reverberating box), the frequency bandwidth of an arbitrary RF pulse must be within the spectrum of the impulse response.

III. NUMERICAL SIMULATION

A. Simulation Setup

A model of the reverberating box with an aperture was simulated using SEMCAD, a Finite Difference Time Domain based computer code [11]. As shown in Fig. 4, the dimensions of the box were 1.8m×1.2m×1.1m (W×H×L). The aperture was placed on the broad side of the box with dimensions of 1m×0.4m (W_a×H_a). The box parameters used in the model are similar to those used in [9]. Port 1 was modeled as a fat dipole, and is located at a distance of 1.5m from the aperture and 0.55m to the right of the boresight axis. Along the plane perpendicular to the boresight axis at 1.5m from the aperture, sensors were placed to record the signal at locations other than Port 1 to examine the degree of spatial focusing. Port 2 (TRM) was modeled as a monocone antenna and is located on the bottom inside, near the back left corner. The walls of the box were assumed to be perfectly conducting.

B. Simulation Results

The approximate impulse response, $h_2(T;T)$, was simulated by transmitting a 300ps Gaussian pulse from Port 1, and recording the response at Port 2 for $T=400$ns (see Fig. 5). $h_2(T;T)$ was then time reversed and retransmitted from Port 2, and the signals were recorded at Port 1 and along the sensor plane to examine the temporal (reconstruction of the short pulse) and spatial focusing. Fig. 6a shows the signal received at Port1, which corresponds to $x(t)$ in Eqn.(5). In the figure, a short pulse that peaks near $t=T$ with the PW of 300ps, which resembles the original pulse, is observed with the peak to “noise” ratio, P/N, of ~15dB, indicating a good temporal compression of the TR impulse response. Note that the signal amplitude is not quantified, since the purpose of this paper is to examine the focusing properties in a relative sense. In Fig. 6b, the peak power levels ($\max(\{x(t)\})$) recorded across the planar sensors are shown. Spatial focusing is clearly observed around the Port 1 location ($x=y=0$), with the half-power focal area of approximately 0.3×0.4m².
Next, a particular RF pulse, \( x_p(t) \), of 5ns PW at 2.3GHz frequency was chosen and convolved with the time-reversed impulse response, \( h_t(T-t;T) \). The convolved signal, \( x_p(t) \ast h_t(T-t;T) \), was then transmitted from Port 2 and recorded at Port 1. The signal received at Port 1, which is now represented by \( x_r(t) \) in Eqn. (6), is shown in Fig. 7a. A pulsed RF very close to the original signal is observed at \( t = T = 400 \text{ns} \), with P/N of ~10dB. The peak power levels recorded across the planar sensor array are shown in Fig. 7b. In this figure, the Port 1 location (x=0, y=0) is at the upper right corner in the plot. Spatial focusing is also observed in this case with the full half-power focal area approximately 0.2x0.45m².

IV. EXPERIMENT

A. Experimental Setup

Measurements were made with the reverberating box with an aperture placed in a large anechoic chamber as shown in Fig. 8. The dimensions of the box were 1.22m × 1.27m × 0.65m (W×H×L). The TRM (Port 2) in the box was a small monochrome antenna placed in the bottom of the box left of center. The aperture dimensions were 0.7m × 0.4m (W×Hₐ). At a distance of 1.9m from the aperture in the boresight direction, an ultra-wideband antenna was placed in a planar scanner to measure the response at different locations. The original Port 1 location was set to 0.5m above and 0.4m to the right of the boresight axis. In this experiment, a network analyzer was used to measure the \( S_{21} \) frequency response (from 0.01-15GHz) between the ports, which was then Fourier transformed into the time domain to obtain an approximation to the time-domain impulse response. The frequency step was set to about 2.34MHz, which yielded the equivalent record time, \( T \), of about 427ns.

Fig. 8. Measurement setup: a) reverberating box with an aperture, where \( W=1.22\text{m} \) (width), \( H=1.27\text{m} \) (height), \( L=0.65\text{m} \) (length), \( Wₐ=0.7\text{m} \) (aperture width), and \( Hₐ=0.4\text{m} \) (aperture height), and b) setup diagram. The planar positioner for the antenna was located at \( D=1.9\text{m} \) from the aperture.

Fig. 9. Experimental impulse response, \( h_{t}(T-T) \), obtained from the frequency response (10MHz-15GHz).
Due to a limited equipment bandwidth, the retransmission of the TR signals \( h_2(T-t;T) \) or \( x_p(t) \otimes h_2(T-t;T) \) in its fullbandwidth was not possible. However, by taking advantage of the spatial reciprocity theorem, retransmission from Port 2 was effectively estimated by convolving the TR signals with \( h_1(t;T) \), so as to approximately represent the reconstructed signals in Eqns. (5) or (6). For examining spatial focusing, the TR signal was simply convolved with the impulse response measured at different locations of the planar scanner.

**B. Experimental Results**

The impulse response, \( h_2(t;T=427\text{ns}) \), obtained from the network analyzer measurement is shown in Fig. 9. The

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**Fig. 10.** Experimental results of estimating the retransmission of the time-reversed impulse response, \( h_2(T-t;T) \): a) Reconstructed signal \( x_p(t) \) at Port 1, and b) Peak values recorded at different positions of planar scanner (perpendicular to the boresight direction), where the location of Port 1 is (0,0).

**Fig. 11.** Experimental results for \( x_p(t) = 7\text{GHz}, 5\text{ns} \) pulsed: a) Reconstructed signal \( x_p(t) \) at Port 1, and b) Peak values (power level) obtained at different positions of planar scanner, where the location of Port 1 is (0,0).

**Fig. 12.** Experimental results for \( x_p(t) = 9\text{GHz}, 5\text{ns} \) pulsed: a) Reconstructed signal \( x_p(t) \) at Port 1, and b) Peak values (power level) obtained at different positions of planar scanner, where the location of Port 1 is (0,0).

**Fig. 13.** Experimental results for \( x_p(t) = 3\text{GHz}, 20\text{ns} \) pulsed: a) Reconstructed signal \( x_p(t) \) at Port 1, and b) Peak values (power level) obtained at different positions of planar scanner, where the location of Port 1 is (0,0).
Table 1. Comparison of the results presented in Figs. 6-7 (simulation) and 10-13 (experiment).

<table>
<thead>
<tr>
<th>Corresponding Figure</th>
<th>Signal Transmitted from TRM</th>
<th>Frequency (GHz)</th>
<th>RF Pulse Width-RFPW (ns)</th>
<th>Wavelength (m)</th>
<th>D (m)</th>
<th>W_a×H_a</th>
<th>P/N (dB)</th>
<th>Estimated Minimum Focal Area (m×m)</th>
<th>Obtained Focal Area (m×m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>h_0(T−t;T)</td>
<td>2.2</td>
<td>N/A</td>
<td>0.14</td>
<td>1.5</td>
<td>1.0×0.4</td>
<td>15</td>
<td>0.18×0.46</td>
<td>0.3×0.5</td>
</tr>
<tr>
<td>7</td>
<td>x_p(t)⊗h_0(T−t;T)</td>
<td>2.3</td>
<td>5</td>
<td>0.13</td>
<td>1.5</td>
<td>1.0×0.4</td>
<td>10</td>
<td>0.18×0.45</td>
<td>0.2×0.5</td>
</tr>
<tr>
<td>10</td>
<td>h_0(T−t;T)</td>
<td>7</td>
<td>N/A</td>
<td>0.043</td>
<td>1.9</td>
<td>0.7×0.4</td>
<td>17</td>
<td>0.11×0.18</td>
<td>0.2×0.3</td>
</tr>
<tr>
<td>11</td>
<td>x_p(t)⊗h_0(T−t;T)</td>
<td>7</td>
<td>5</td>
<td>0.043</td>
<td>1.9</td>
<td>0.7×0.4</td>
<td>10</td>
<td>0.11×0.18</td>
<td>0.15×0.2</td>
</tr>
<tr>
<td>12</td>
<td>x_p(t)⊗h_0(T−t;T)</td>
<td>9</td>
<td>5</td>
<td>0.033</td>
<td>1.9</td>
<td>0.7×0.4</td>
<td>11</td>
<td>0.08×0.14</td>
<td>0.11×0.15</td>
</tr>
<tr>
<td>13</td>
<td>x_p(t)⊗h_0(T−t;T)</td>
<td>3</td>
<td>20</td>
<td>0.1</td>
<td>1.9</td>
<td>0.7×0.4</td>
<td>9</td>
<td>0.25×0.43</td>
<td>0.3×0.45</td>
</tr>
</tbody>
</table>

estimated \( x_p(t) \) at Port 1 is shown in Fig. 10a, where an impulse-like signal that peaks near \( t=T \), is observed with P/N of \(-17\)dB, indicating a good temporal compression. Note again that the signal amplitude is not quantified. Fig. 10b shows the peak power levels (\( \max|x_p(t)|^2 \)) at different locations of the planar scanner. Spatial focusing is clearly observed around Port 1 location with the half-power focal area of approximately 0.3m×0.35m.

For arbitrary RF pulses, three different signals, i.e. 1) \( x_p(t) = 7\)GHz with 5ns PW, 2) \( x_p(t) = 9\)GHz with 5ns PW, and 3) \( x_p(t) = 3\)GHz with 20ns PW, were used. Each RF pulse was convolved with the time-reversed impulse response, \( h_0(T−t;T) \). The resulting signal was then convolved again with the corresponding impulse responses at each scanner location to estimate the reconstructed signal, \( x_1(t) \), \( x_2(t) \), and \( x_3(t) \) for each respective RF pulse, as shown in Figs. 11a, 12a, and 13a. In all cases, a pulsed RF that resembles the original signal is observed at \( t=T \), with reasonable P/N values. In Figs. 11b, 12b, and 13b, the peak power levels at different planar scanner locations are shown for each corresponding case. Spatial focusing occurred near Port 1 for all cases, and the focal area is proportional to the wavelength (inversely proportional to the RF frequency) as expected - i.e., \( 0.3×0.45m^2 \), \( 0.15×0.2m^2 \), \( 0.11×0.15m^2 \), for 3, 7, and 9 GHz, respectively. For \( x_p(t) \), the estimated \( x_1(t) \) does not seem to resemble \( x_2(t) \) as closely as in other cases, which indicates a relatively poorer temporal compression.

V. DISCUSSION

A. Comparison of the Results

Table 1 shows a comparison of the results from Figs. 6-7 (simulations) and 10-13 (experiment). In the table, the estimated minimum spatial focal area using Eqn. (4) is also shown. For the impulse responses (results in Figs. 6 and 10), the minimum focal area was estimated using the center frequency of the impulse bandwidth. Also notice that the estimated and observed focal area are not as close as those from the pulsed RF results (Figs. 7, 11, 12 and 13), since Eqn. (4) only estimates the focal area at one frequency. In all cases the observed focal area is slightly larger than the estimated minimum, due to some approximations used in Eqn. (4) (i.e. based on a uniform aperture distribution and \( \Delta \)) approximated from the arc length of the half-power angle in the aperture radiation pattern) and the port 1 location being off the
boresight axis (i.e. the beamwidth broadens when off the boresight). Overall, the results are promising and indicate that reasonable temporal and spatial focusing of an arbitrary RF pulse can be achieved through the use of time-reversed impulse response.

**B. Pulse Quality**

As previously mentioned, the quality of the reconstructed pulse is largely determined by losses in the process. In this particular case the loss is mainly caused by: 1) the energy lost in the radiation (never captured by the aperture), 2) the energy lost through the aperture during the reverberation in the box, 3) finite duration of the recorded impulse response, and 4) the conductor loss in the cavity walls and the ports.

By reducing the loss in the process, a better reconstruction may be achieved, particularly improving the P/N. One way to do so is to reduce the size of the aperture. It was shown in [9] that the aperture area of $\sim \lambda^2$ gives the best temporal compression at a given frequency. However, a smaller aperture size results in a larger spatial focal area due to the diffraction limit. Moreover, the electrical size of the aperture varies with frequency. Hence it would be important to determine the parameters that provide optimal temporal and spatial focusing over the frequency band of interest. For the reverse problem (focusing the energy at a target in an enclosure), selecting an optimal frequency band for an effective focusing for given parameters would be of interest.

**VI. SUMMARY AND CONCLUSION**

In this paper we presented a technique to effectively send an arbitrary RF pulse to a localized region at a distance from the source, using the time-reversed impulse response between the desired location (Port 1) and the TRM (Port 2). We also showed that when convolved with an arbitrary RF pulse and transmitted through the TRM, an effective delivery of that pulse to the target location takes place. We demonstrated this technique by extending the concept of a TRM placed in a leaky reverberating box, to transmit a convolved response of the time-reversed impulse response and an arbitrary RF pulse through the TRM. Numerical simulation and laboratory measurements were conducted to examine temporal and spatial focusing of the pulse at Port 1 using RF pulses of different center frequencies and pulsewidths. In all cases, a good temporal compression occurred at time $t = T$ (the recording time of the signal) as expected, with the signal $x_r(t)$ closely resembling a time-reversed version of the original pulse. Spatial focusing was also observed with the focal area in agreement with estimates based on the diffraction limit. It was clearly seen from the results that an RF pulse can be effectively delivered using the TRM if the impulse response between the desired location and the TRM can be obtained.

This approach could potentially be used for selective “beamforming” of an HPM system to effectively deliver an RF pulse of choice using the pre-stored (or obtained on-the-fly) impulse response for a given target location. Alternatively the system can be used as well to focus energy at a targeted location in an enclosed system that has one or more entry points for electromagnetic energy. One limitation of this method is that the spatial focusing of the signal in a scenario similar to that depicted in Fig. 1(b) will be limited by the aperture size. However the peak field created in the reconstructed pulse has been shown to be independent of the aperture size [9].

Currently under investigation are techniques to improve the quality of the reconstructed pulse in terms of pulse shape, P/N (temporal focusing) and the spatial focusing. Examining different TRM parameters and structures (i.e. a ray-chaotic box, different aperture), as well as different TR pre-processing are also under investigation and will be the subject of future publications.

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**REFERENCES**


Sun K. Hong (S'06-M'10) received his B.S. in electrical engineering from the University of Maryland, College Park, MD in 2003 and M.S. in electrical engineering from Virginia Tech, Blacksburg, VA in 2008. He is currently a Ph.D. candidate in electrical engineering at Virginia Tech. He is currently a research engineer in the Tactical Electronic Warfare Division at the US Naval Research Laboratory (NRL), where he started as a student contractor in 2003. His current research interests include transient backscatter and detection algorithms, as well as time-reversal techniques in electromagnetics. He is also involved in modeling of EM interactions with laser induced plasma channels. Some of his recent/past involvement includes HPM effects, antenna design for HPM application and UWB measurements, and RF propagation model in multipath environment. Mr. Hong is a member of Eta Kappa Nu. He is also a visiting scholar in the Ultrafast and Nonlinear Photonics Lab at the Johns Hopkins University, Baltimore, MD, and is collaborating in the.

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Steven M. Anlage (M’94) is a Professor of Physics and faculty affiliate of the Department of Electrical and Computer Engineering at the University of Maryland, College Park. He received his B.S. degree in Physics from Rensselaer Polytechnic Institute in 1982, and his M.S. and Ph.D. in Applied Physics from the California Institute of Technology in 1984 and 1988, respectively. His graduate work concerned the physics and materials properties of quasicrystals. His post-doctoral work with the Beasley-Geballe-Kapitulnik group at Stanford University (1987 - 1990) concentrated on high frequency properties of high temperature superconductors, including both basic physics and applications to tunable microwave devices. In 1990 he was appointed Assistant Professor of Physics in the Center for Superconductivity Research at the University of Maryland, then (1997) Associate Professor, and finally (2002) Full Professor of Physics. He was the interim Director of the Center for Nanophysics and Advanced Materials (2007-2009), and is a member of the Maryland NanoCenter. There his research in high frequency superconductivity has addressed questions of the pairing state symmetry of the cuprate superconductors, the dynamics of conductivity fluctuations and vortices, and microwave applications such as superconducting negative index of refraction metamaterials. He has also developed and patented a near-field scanning microwave microscope for quantitative local measurements of electronic materials (dielectrics, semiconductors, metals, and superconductors) down to nm length scales. Prof. Anlage also performs microwave analog experiments of the Schrödinger equation to test fundamental theories of quantum chaos. As part of this work he has developed a statistical prediction model for effects of high-power microwave signals on electronics. He is also active in the emerging field of time-reversed electromagnetics. Dr. Anlage is a member of the American Physical Society, the IEEE, the Optical Society of America, and the Materials Research Society. His research is funded by the National Science Foundation and DoD, and he is an active consultant to the US Government. He was a member of the NSF-funded Materials Research Science and Engineering Center at the University of Maryland from 1995-2005. In 2008 Dr. Anlage was appointed a Research Professor of the National Security Institute at the Naval Postgraduate School in Monterey, CA. He has co-authored more than 130 research papers in scientific journals.

Tim D. Andreadis received his B.S. in Physics and Ph.D. in nuclear engineering respectively in 1974 and 1981, both from the University of Maryland, College Park, MD. He is currently the head of the High Power Microwave section at the US Naval Research Laboratory, Washington, DC. The HPM section is engaged in work that includes research on HPM effects on electronics, counter IED applications, high power RF source applications, and electromagnetic backscatter.

Dr. Andreadis has served as a Navy representative to the DoD HPM Steering Group, the DoD Technology Panel on Directed Energy Weapons, and NATO panels on HPM effects. He also serves on the JIEDDO Directed Energy Review Group. He is a fellow and the vice president of the Directed Energy Professional Society. Dr. Andreadis has an extensive list of peer reviewed publications, conference proceedings, and reports. He has numerous invited talks and presentations at national and international conferences. He received