Modeling Reverberation Time Series for Shallow Water Clutter Environments

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Introduction: The phenomenon of clutter in shallow water environments can be modeled from several approaches. One approach we have taken is to model reverberation time series for heterogeneous environments with a variety of scattering mechanisms to compare the resulting characteristics to those of experimentally observed clutter. Here we show R-SNAP[1] reverberation time series estimates for the Malta Plateau region in the Straits of Sicily that seem to capture some of the clutter behavior observed during the SCARAB 98 experiment conducted in conjunction with the NATO Undersea Research Centre (NURC), Italy.[2] Of particular interest is the appearance of coherent time-frequency striation patterns in both the modeled and observed reverberation, with spatially compact, broadband clutter features superimposed by the presence of environmental discontinuities.

Malta Plateau Reverberation Characteristics: The Malta Plateau is a shallow (70–200 m) site in the Straits of Sicily north of Malta. It is characterized by a muddy bottom lying over consolidated sediment/rock that becomes exposed as the Ragusa Ridge, which runs north-south between Malta and eastern Sicily. In Fig. 1, reverberation in the 100 Hz to 2 kHz band for a 91 m impulsive SUS charge is shown superimposed on the bathymetry for the site. These data were collected during the SCARAB 98 trial conducted by SACLANTCEN (now NURC) on a conventional (ambiguous) array towed in the north-south direction.[2,3] Clearly evident is reverberation clutter associated with a region of shoaling bathymetry and thinning sediment cover on the Ragusa Ridge to the east of the ship track. Also evident are strong scattering events from certain known wrecks to the south and east of the source and from the Campo Vega oil production platform to the NNW (approximate locations are indicated by black crosses).

Figure 1 shows that there are at least two types of clutter in the SCARAB 98 data set: environmental clutter characterized by increased reverberation from the exposed ridge, and target-like clutter events associated with anthropogenic sources such as shipwrecks and oil productions facilities. Figure 2 shows the spectrogram of the SUS reverberation seen on the bearing of 116 true from Fig. 1. Here one can observe the broadband nature of both the discrete clutter event seen at 15 s caused by a sunken ship, and the extended clutter return from the Ragusa Ridge from 19 to 24 s. One also observes many other smaller clutter events, probably associated with smaller environmental discontinuities, which are most energetic between 1 and 2 kHz. Superimposed on these features is the time-frequency structure of coherent round-trip propagation to the scatterers in the waveguide, characterized by a clearly visible striation pattern typically associated with passive acoustics in shallow water waveguides[4] but here clearly evident in the active acoustic reverberation.

Malta Plateau Environmental Description: A detailed geoacoustic and scattering description of the environment between Sicily and Malta has been prepared by Charles Holland at the Applied Research Laboratory at the Pennsylvania State University (ARL/PSU) based on measurements of propagation, scattering strength, and reverberation.[3] The results are shown in Table 1. Notice that both the sediment attenuation and the scattering strength grow linearly with frequency. Using the values in Table 1 gives good agreement between the data and the range-independent model results for the background levels of reverberation on the sediments of the Malta Plateau, away from the Ragusa Ridge. We use these background environmental parameters, along with detailed measurements of the bathymetry and sediment thickness on the Malta Plateau collected by Osler and Algan,[5] to model environmental clutter from the Ragusa Ridge.

Malta Plateau Simulation Results: Using the environmental parameters in Table 1, the detailed bathymetry and sediment thickness measurements of Osler and Algan, and the SUS source spectrum and towed array beamwidth, we exercised the time series generation capability of R-SNAP to simulate environmental clutter for the 337.5–362.5 Hz band over the Ragusa Ridge from the sediment-water and sediment-basement interfaces. Figure 3 compares the measured data, shown in blue, and the simulation (minus 30 dB), shown in red. Agreement is quite good, up to and including the clutter enhancement associated with the ridge, which in the model is captured by the exposure of the sediment-basement interface to acoustic energy where the sediment cover thins dramatically. Figure 4 shows the spectrograms of the data and the model. Note the time-frequency striations visible in the data (b) are replicated in the simulations (a). Overall, many aspects of the clutter caused by the Ragusa Ridge are faithfully replicated in the simulations.

Conclusions: The R-SNAP code has been exercised to model environmental clutter caused by an exposed ridge on the Malta Plateau south of Sicily. Model-data comparisons at 350 Hz show favorable agreement between the reverberation data from the ridge and the simulations using average environmental parameters

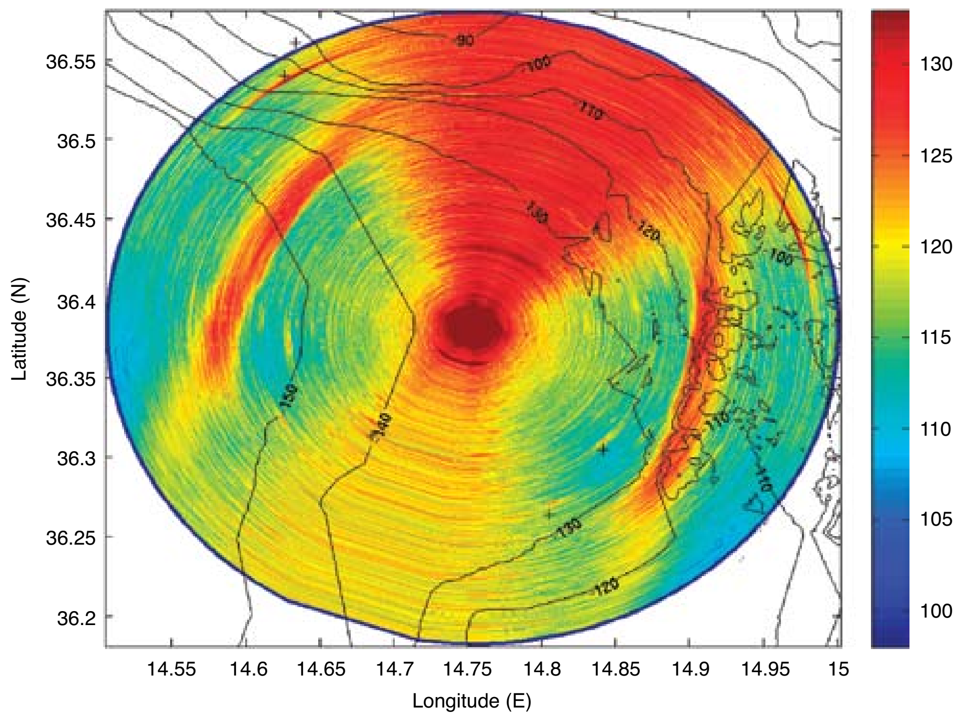


FIGURE 1
Reverberation data collected on the Malta Plateau. Ambiguous clutter returns from the Ragusa Ridge are clearly visible. Clutter from wrecks (south of the receiver) and the Campo Vega oil production platform (northwest of the receiver) is also visible. Known approximate positions of these objects are indicated with crosses.

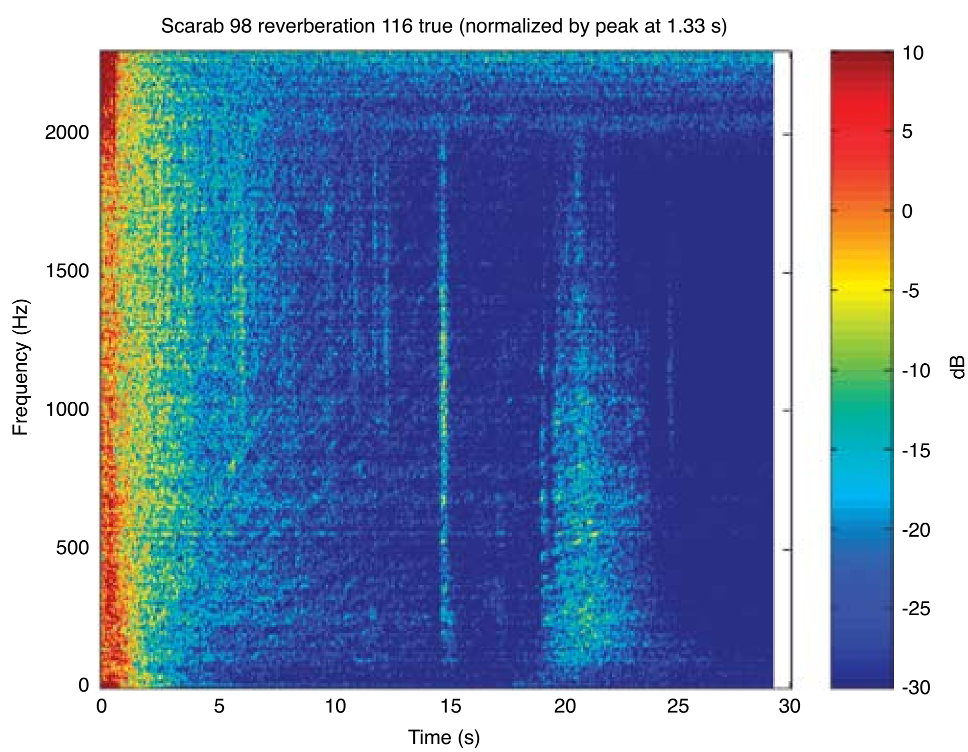


FIGURE 2
Time-frequency spectrogram of SUS reverb looking towards shipwreck (15 s) and Ragusa Ridge (18–25 s).

TABLE 1
Background Environmental Properties for Malta Plateau

PROPERTY	VALUE
Sediment Sound Speed Ratio	1.05
Sediment Density	1.80 gm/cm^3
Sediment Attenuation (dB/l)	0.70 f (f in kHz)
Sediment Scattering Strength (Lommel-Seeliger)	–47 + 14.8 f (f in kHz) dB
Basement Scattering Strength (Lommel-Seeliger)	–15 dB

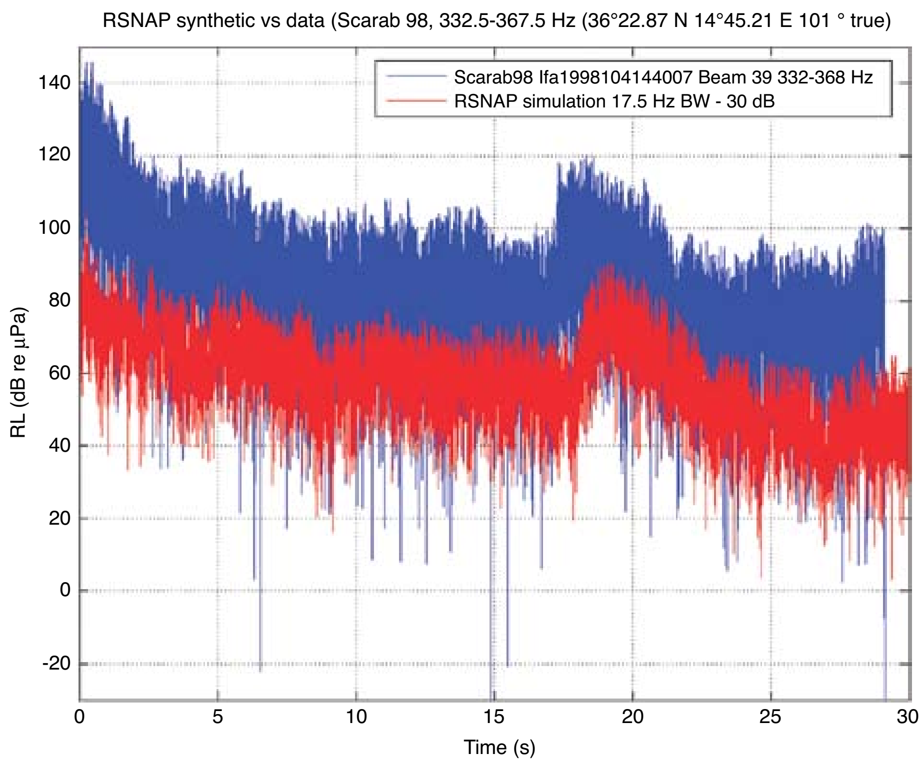
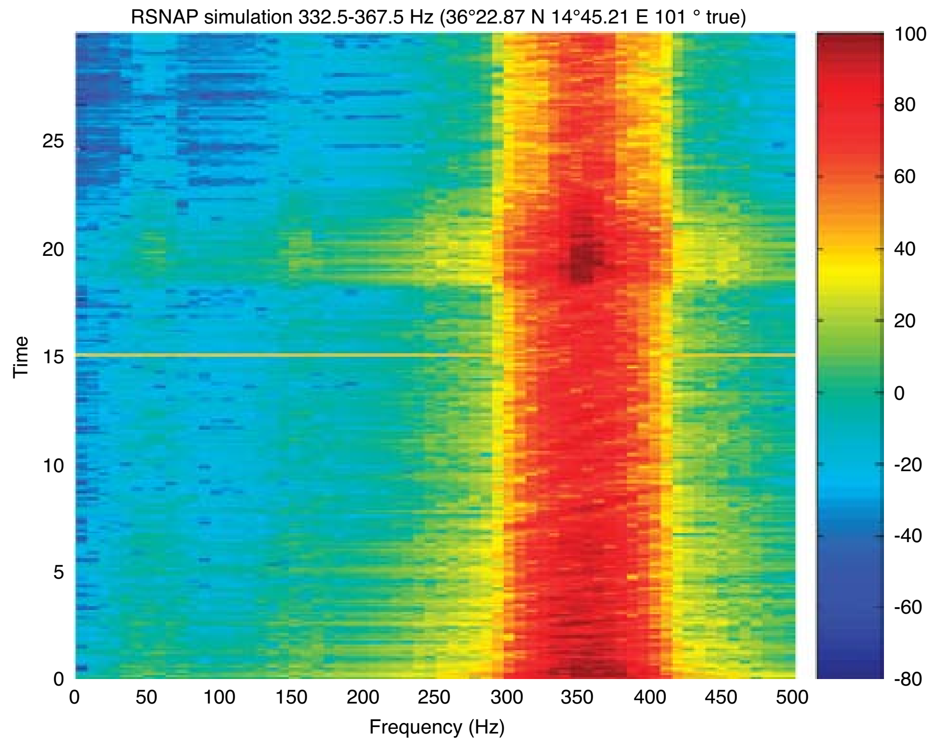
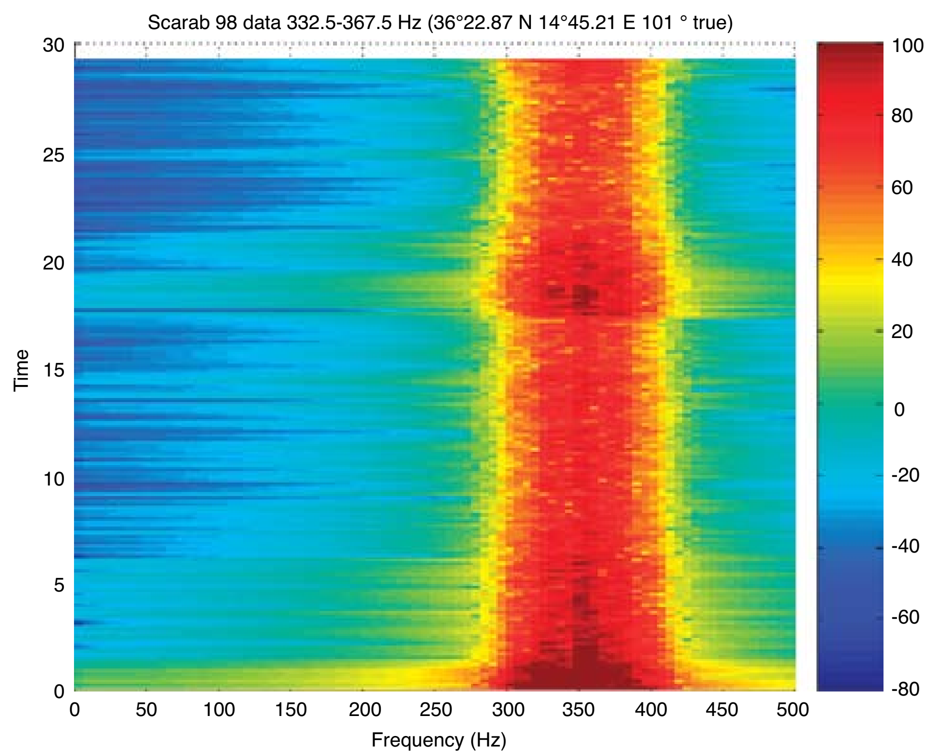


FIGURE 3
Narrowband reverberation time series in the 332–368 Hz band measured from the Ragusa Ridge on the Malta Plateau during SCARAB 98 (blue), and simulated by R-SNAP for the same frequency band (red, offset by 30 dB) using environmental parameters measured in situ. The simulation captures many of the characteristics of the measured data.



(a)



(b)

FIGURE 4
Spectrograms of (a) 350 Hz R-SNAP simulation shown in Fig. 3, and (b) SCARAB 98 data. Many of the characteristics of the data are captured by the simulation, including coherent time-frequency striations of positive slope and the clutter return from the Ragusa Ridge starting at 18 s.

supplied by an independent analysis. This agreement includes both the presence of coherent time-frequency striations in the data, and strong clutter enhancements over the Ragusa Ridge. The results illustrate that with sufficient environmental knowledge, certain clutter characteristics of shallow water reverberation associated with large environmental inhomogeneities may be predicted. The R-SNAP tool is at the vanguard of a new generation of reverberation models that are capable of predicting coherent reverberation time series for well-characterized shallow water waveguides. Time series simulation allows the estimation of sonar clutter for notional systems of interest.

[Sponsored by ONR]

References

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[4] G.L. D'Spain and W.A. Kuperman, "Application of Waveguide Invariants to Analysis of Spectrograms from Shallow Water Environments that Vary in Range and Azimuth," *J. Acoust. Soc. Am.* **106**(5), 2454–2468 (1999).

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