Exploring potential applications of Gaussian Ball Filters in Sharpe's Hollow Cavity Model (SHCM)

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Introduction

In previous studies we have investigated the viability of the SHCM in modeling explosive pressure sources (Petten, 2012). We found that the SHCM was able to predict with reasonable accuracy several important features of the frequency spectra obtained from a series of surveys. The relationship between the charge size and cavity radius in the SHCM is crucial for utilizing the model to its full potential; the Gaussian Ball model described by Aldridge may provide a starting point for establishing the relationship between cavity radius and charge size as the width of the Gaussian Ball influences the behavior of the frequency spectra (Aldridge, 2011).

Gaussian Ball Model

The Gaussian Ball Model as described by Aldridge assumes that a charge can be represented as a point source in space that has an instantaneous energy release into its surroundings (as shown in Figure 1). A pressure pulse in this model can be expressed as a convolution in the time domain of a "Gaussian explosion filter" with a point source pressure, such that

$$p_G(r,t) = p_o(r,t) * g(r,t), \qquad (1)$$

where p_G is the pressure trace obtained from the Gaussian Ball model, p_o is the pressure trace for a point source, and g is the Gaussian Explosion filter. The pressure trace for the point source is defined as,

$$p_o(r,t) = \frac{M\left(1 - 4\gamma^2/3\right)}{4\pi\alpha^2 R} w(t), \qquad (2)$$

where R is the distance from the point source to the receiver, α is the p-wave speed, γ is the ratio of p- to s-wave speed, M is a magnitude scalar, and $w(t)$ is an arbitrary source activation waveform. Equation 1 can be written in the frequency domain as

$$p_G(\omega) = M p_o(\omega) G(\omega) \qquad (3)$$

with:

$$G(\omega) = \exp\left[-\left(\frac{h\omega}{2\sqrt{\pi}\alpha}\right)^2\right], \qquad (4)$$

where h is the width of the Gaussian Ball filter. Also note that in Equation 3 the magnitude scalar has been taken outside of the expression for the point source pressure pulse. Figures 2 and 3 shows a pressure pulse that has been obtained from the Gaussian Ball model using Equation 3. Note that the Gaussian Ball filter changes both the amplitude dominant frequency of the trace.

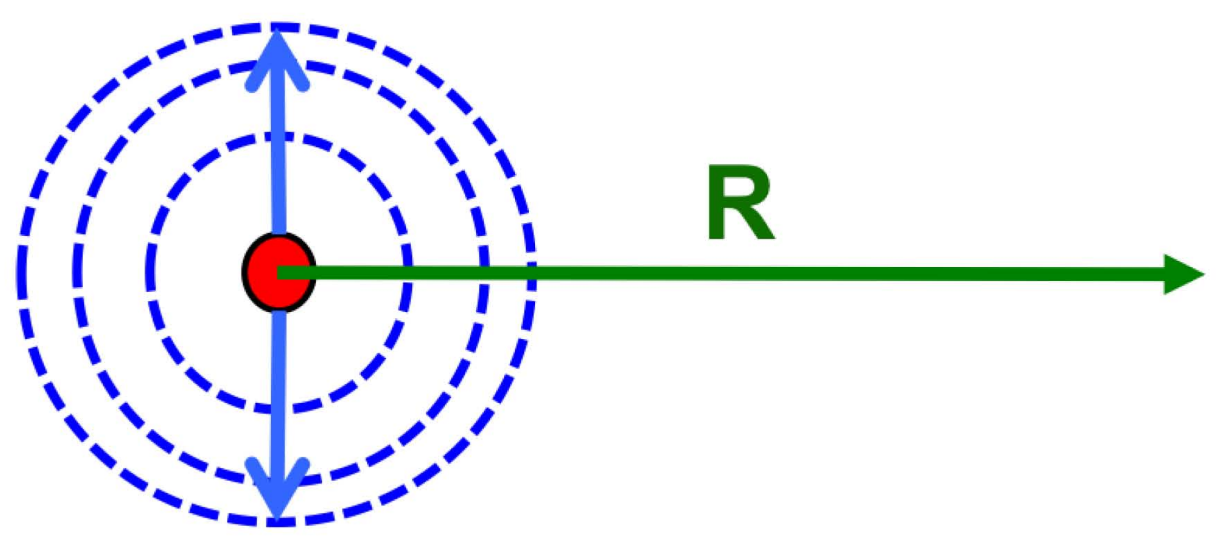

Figure 1 : Graphical depiction of the Gaussian Ball model. This model assumes that the charge can be represented as a point source in space that activates via application of an activation waveform which results in an instantaneous release of energy into the surroundings.

Gaussian Ball Filters

Figure 4 shows a series of Gaussian Ball filters in both the time and frequency domain. As the width of the Gaussian Ball grows in the time domain, it shrinks in the frequency domain. One of the most significant results of Sharpe's model is the fact that dominant frequency decreases with increased cavity radius. If we assume that h corresponds to charge size, this phenomenon could account for the variance of the cavity radius in Sharpe's model with charge size.

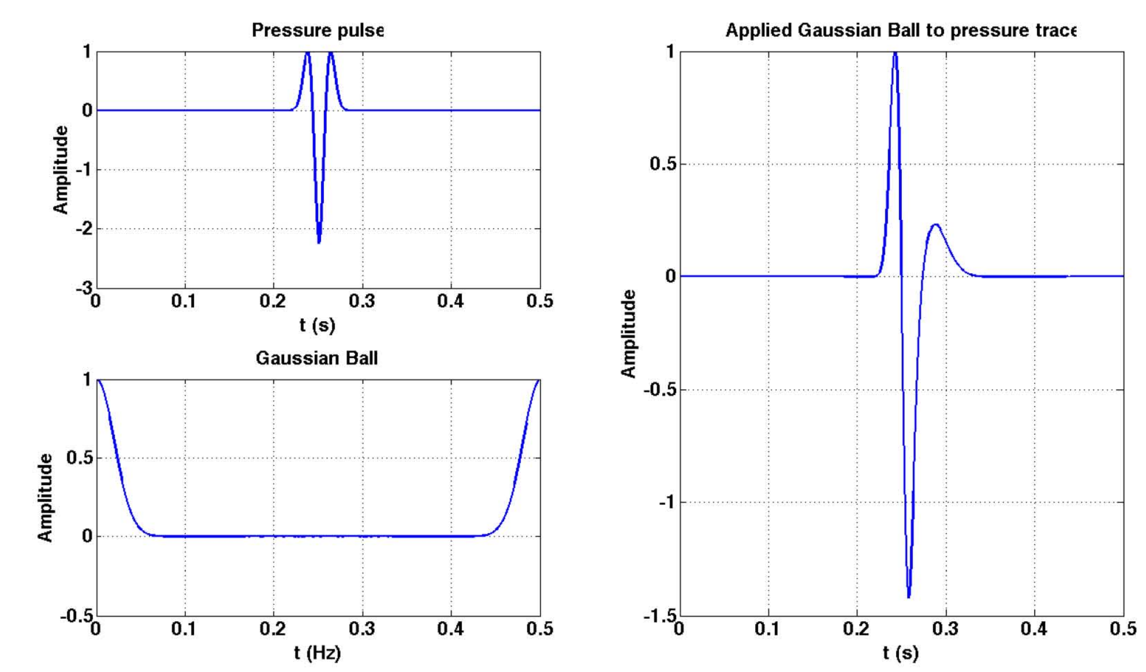

Figure 2 : A pressure pulse in the time domain obtained from the Gaussian Ball model using Equations 1 through 4.

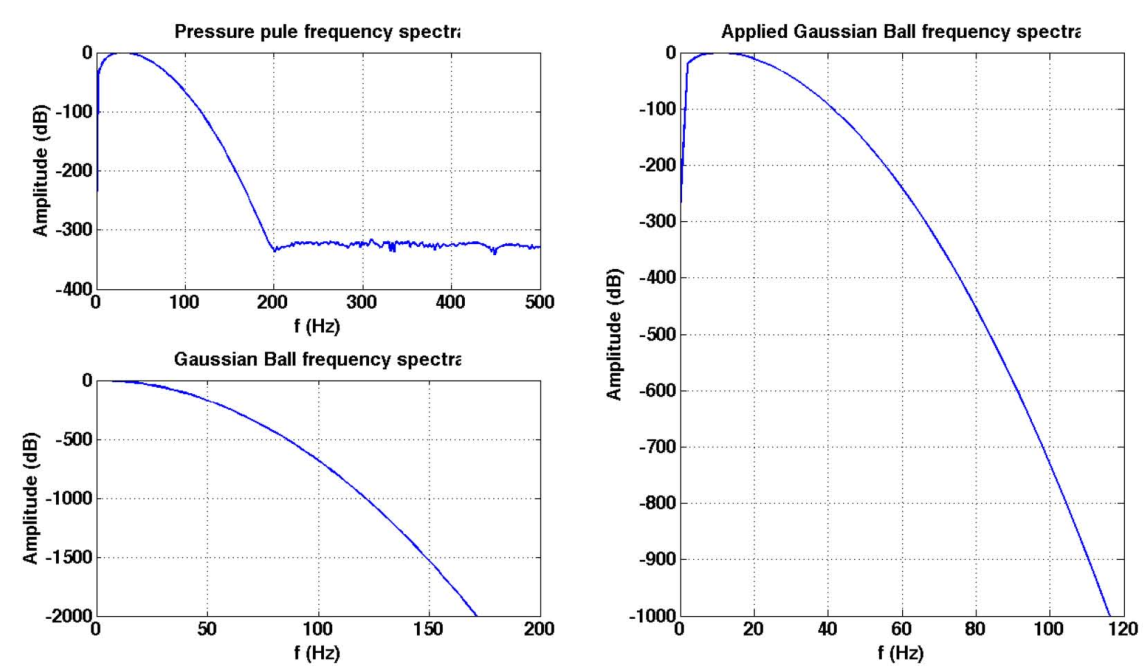

Figure 3 : The frequency spectra for the pressure pulse and Gaussian Ball filter shown in Figure 2. Note that the Gaussian Ball modifies both the amplitude and the dominant frequency of the pulse.

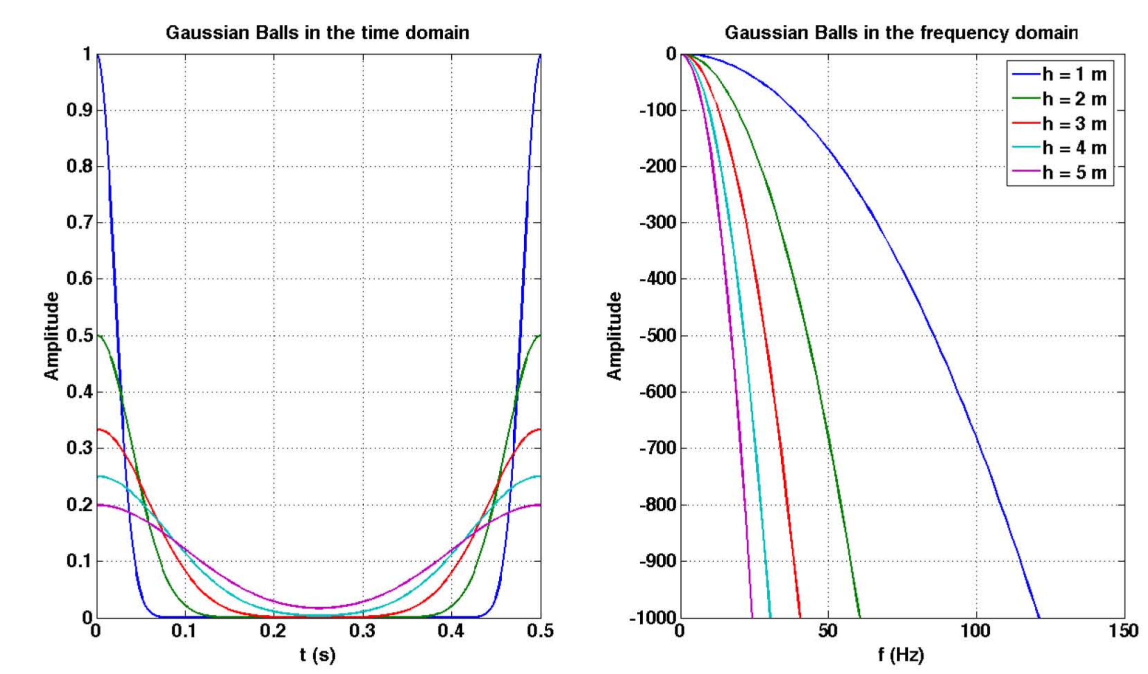

Figure 4 : A series of Gaussian Balls obtained from Equation 4. Note that as the width of the Gaussian Ball decreases in the time domain, it broadens in the frequency domain. This could explain how cavity radius varies with charge size in Sharpe's Model.

Ricker Wavelet Input

In a previous study we found strong evidence to support the idea that the charge size is related to the cavity radius via a cubic relationship (Petten, 2012). Therefore, for this study we assumed that the magnitude is also related to the Gaussian Ball width via a cubic relationship such that

$$M = h^3. \qquad (5)$$

Under this assumption we created a series of frequency spectra using a Ricker wavelet as a source activation waveform and convolving it with a series of Gaussian Ball filters of varying magnitude and ball width as per Equation 5. We found that the dominant frequency decreased with increased ball width, while the amplitude response increased with ball width. These results are very similar to cavity radius in Sharpe's model.

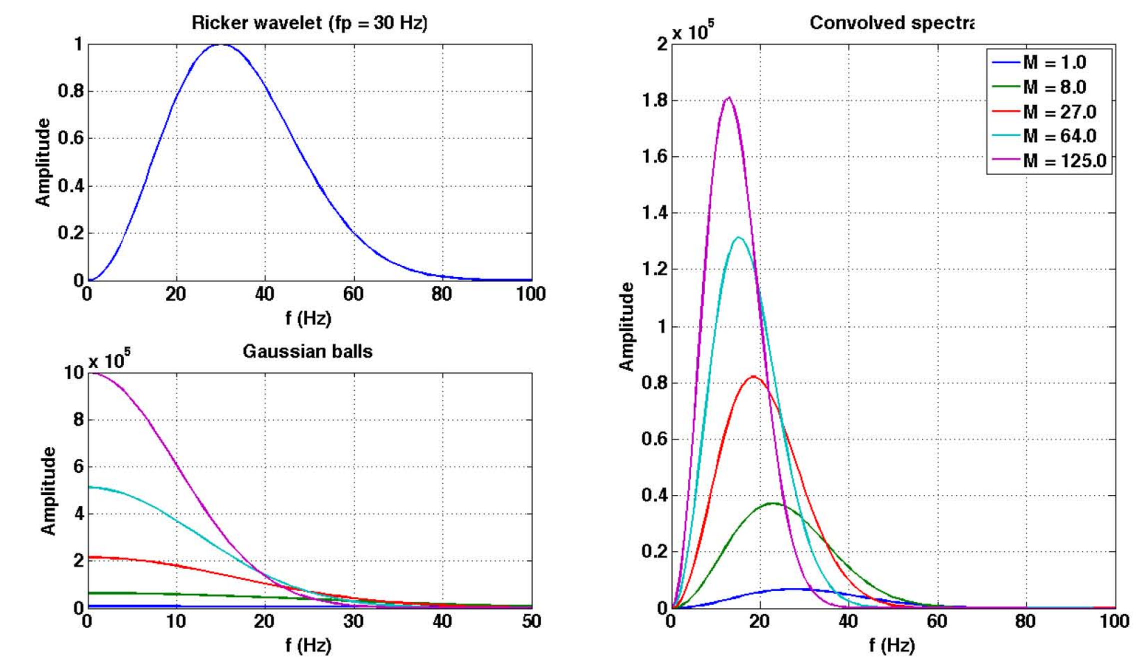

Figure 5 : A Gaussian Ball model obtained by convolving a point source with a Ricker wavelet for a source activation waveform, convolved with a series of Gaussian Balls with varying width and magnitude.

Conclusions

There were three significant results in the Sharpe Hollow Cavity Model that we noted in a previous study. These features include a low frequency roll off that is present in the lower end of the spectrum, a decrease in dominant frequency with increased charge size, and an increased amplitude response. Observation of Figure 5 shows that the Gaussian Ball model produces the same results provided that we use a Ricker wavelet as the source activation waveform, and we assume a cubic relationship between magnitude and ball width as per Equation 5. The behavior observed here can most likely be attributed to the Gaussian Ball (Figure 4) and may be applicable to the Sharpe model.

Bibliography

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