DIGITALLY CODED ELECTROMAGNETIC TRANSDUCERS

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ABSTRACT

Electromagnetic transducers had previously been shown to be capable of acting as pulse compressors to achieve improved range resolution. Compression was achieved using pairs of transducers designed to produce or detect a burst with a linear frequency variation. An alternate approach, which is also easier to fabricate, is to impress a digital phase code on single frequency coils. One such code with good autocorrelation properties is the 13 bit Barker coder. Coils with this code were fabricated and evaluated. It will be shown that the operation of these devices is very similar to the coils with dispersive designs. The waveforms, compression ratio, and sidelobe levels to be expected from these devices are described.

Introduction

In a previous paper[1], it was shown that one inherent problem with electromagnetic surface acoustic wave transducers (SAW EMT's) is poor range resolution due to the long tone burst outputs of the devices. One solution to the problem is the use of pulse compression techniques which were developed originally for radar applications to achieve an output pulse from the receiving transducer which is comparable to the broadband pulse normally used for NDE ultrasonic inspections. In the previous work, the pulse compression scheme chosen for evaluation was the use of a transducer designed to produce a chirp signal which is a tone burst within which the frequency varies linearly with time. When such a signal is received by an identical transducer, it is compressed by an amount equal to the pulse width-bandwidth product.

One problem with the chirp design is the difficulty of fabrication since the high frequency segment of the chirp normally requires very narrow line spacings which are near the limit of resolution of the present photoetch production technique. An alternative scheme which is very much easier to fabricate is to digitally phase code[2] the output waveform of a transducer which is basically a single frequency device. Of the large number of codes available[2], the 13 bit Barker code was selected for use with SAW EMT's because it was best able to give the required performance within the constraints imposed by the physical nature of the EMT. These constraints were as follows: First, for ease of fabrication, the bits should be composed of complete cycles with each bit at 0° or 180° phase difference. Second, the largest number of lines which can be effectively utilized with the permanent magnets available is on the order of 30. Since line spacing is 1/2 wavelength, two lines are required for the minimum length bit, the maximum number of bits is on the order of 15. Third, the code should have minimum sidelobe levels.

The Barker codes fulfill the third constraint very well. This class of codes has sidelobe levels at 0 or 1 with the main peak at level N where N is the number of bits[2]. A 13 bit code is the maximum length code in the Barker class and this code would require a 26 line EMT coil if each bit is one cycle. Thus, this code fulfills all the constraints.

Design and Operation

The coil design for the Barker 13 bit phase coded EMT is shown in Fig. 1. The thick outside lines are current return paths which are not meant to generate significant acoustic amplitude. In the first design these lines were of the same thickness as the lines in the active part of the coil. It was found that the acoustic signals from these lines were of the same order of magnitude as those generated in the active region. When they were made very thick, however, the current density was lowered and the frequencies at which they could couple to acoustic waves were shifted low enough that no signals were detected from these lines during subsequent tests.

Coils were constructed which were designed to operate at fundamental frequencies of 4 and 7.25 MHz. The output waveform of the 4 MHz coil when it is driven with an approximately 50 n sec wide pulse and exciting surface waves in aluminum is shown in Fig. 2. In this case the receiving transducer is a 10 MHz Panametrics broadband wedge transducer. The permanent magnets were set roughly 1/8" apart since this distance produced the largest output pulse. As can be seen from the figure, the magnet configuration produces a rather strongly peaked field and the acoustic amplitude as a function of position is correspondingly peaked.

When the waveform shown in Fig. 2 is received by an identical transducer the compressor output pulse as shown in Fig. 3 results. The resulting sidelobes do not have the uniform level one would expect for the ideal case. An elementary analysis showed that the peaking of the output pulse gives rise to two effects in the sidelobes. First, the amplitude of the sidelobes increases as the central maximum is approached and second, the points which would normally be zeros reach a finite amplitude. In this case it should be noted that only the sidelobes adjacent to the central maximum are greater than 1/13 of the peak which is the magnitude of all the sidelobes in the ideal case. Thus, the nonuniform amplitude only harms the performance near the central peak. The width of the compressed pulse is slightly greater than 400 n sec, yielding a compression ratio of greater than 7.

An attempt was made to determine the effect on the performance if a more uniform amplitude output were obtained. Rough uniformity in the magnetic field was obtained by inserting a 1/4" spacer between the magnets, considerably reducing the field strength. This magnet configuration produced the output signal shown in Fig. 4 and the corresponding compressed pulse in Fig. 5. As can be seen from these figures, the output pulse is close to the theoretically desired and the sidelobes have much less structure. However, the sidelobe amplitudes still increase as the central maximum is approached and the amplitude of the central peak is reduced by approximately 35% from the previous case.

The Barker 13 bit phase coded coils with the 7.25 MHz fundamental frequency were investigated in a similar manner. The output signal from the pulse excited coil is not shown here because the bandwidth of the piezoelectric transducer receiver was not sufficient to reproduce the rapid phase changes between bits. However, the amplitude was found to be peaked as in Fig. 2 for a similar magnet configuration. The compressed output signal from the transducer pair is shown in Fig. 6. The main difference in this waveform as compared to the output of the 4 MHz units is a reduction in the pulse width. In this case, the compressed pulse is on the order of 200 n sec wide. This pulse width is comparable to that obtained with the 4 MHz bandwidth chirp transducers used in the previous study[1].

Conclusions

It has been shown that a digitally phase coded EMT will perform in a manner comparable to the chirp EMT with the advantage of being easier to fabricate. One distinct disadvantage of this design is the sidelobe levels. With the digital coding there is little one can do to reduce these levels in contrast to possible reductions one can obtain in the chirp case with suitable spectral weighting[2].

References

1. T. J. Moran, 1976 Ultrasonic Symp. Proc., IEEE Cat. #76 CH1120-5SU, p. 26 (1976).
2. C. E. Cook, M. Bernfeld, and C. A. Palmieri, Microwave Journal, pp. 73-81, Jan. 1965.

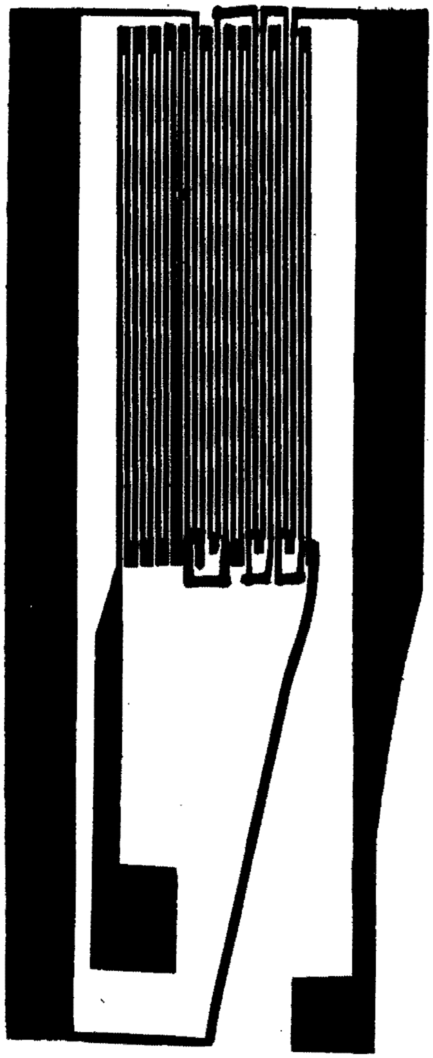

Figure 1. Coil design for 13 bit Barker coded EMAT..

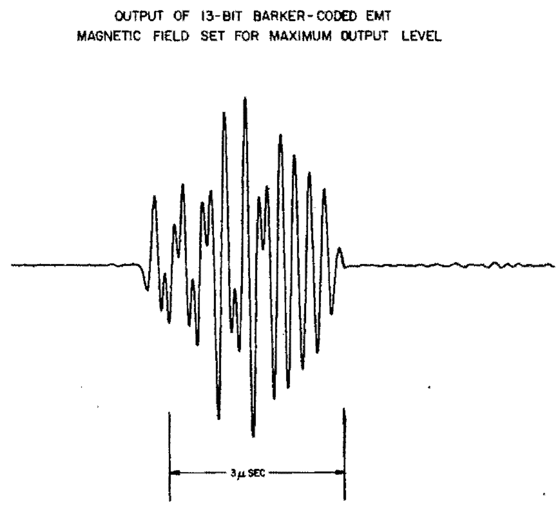

Figure 2. Output of a single 13 bit Barker coded EMAT which is pulse excited. Signal propagated on aluminum and received with a piezoelectric transducer, f = 4 MHz.

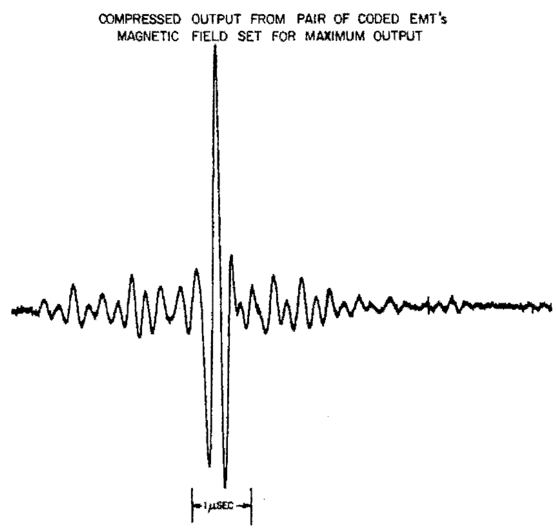

Figure 3. Response of an identical 13 bit Barker coded EMAT to the signal shown in Fig. 2.

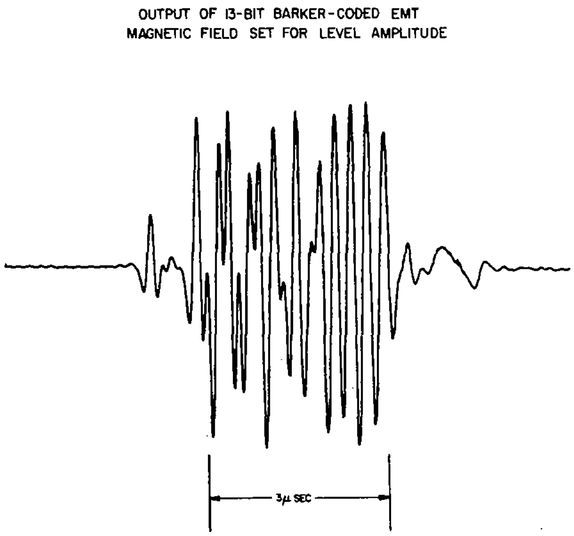

Figure 4. Nearly uniform amplitude output signal from a 13 bit Barker coded EMT achieved by using magnets with a wider spacing between the pole faces. Piezoelectric receiver.

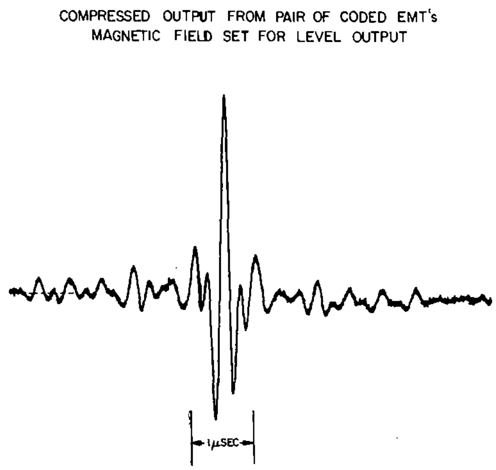

Figure 5. Response of an identical 3 bit Barker coded EMT to the signal shown in Fig. 4. Note the decrease in the number of side-lobes.

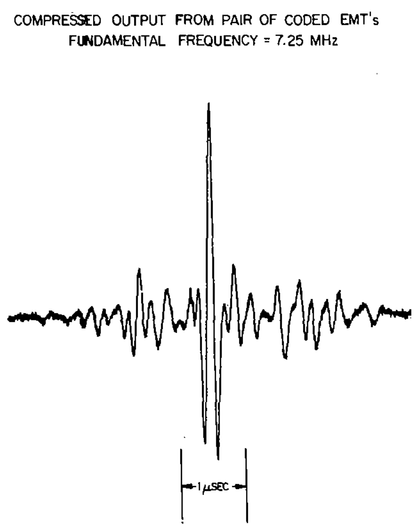

Figure 6. Response of a pair of 13 bit Barker coded EMT's operating with a fundamental frequency of 7.25 MHz. Note the narrowing of the compressed pulse as compared to the MHz devices.