A NOVEL MSW PROGRAMMABLE BARKER CODER/DECODER

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ABSTRACT

A thirteen-bit Barker coder and correlator was designed and built which uses a novel technique for phase encoding the signal, based on small d.c. magnetic fields generated by current loops surrounding each one of thirteen delay lines. The experimental results presented correspond to a reduction of the number of bits to seven.

INTRODUCTION

The possibility of using magnetostatic wave tapped delay lines for a programmable bi-phase pulse encoder application has already been explored by T. W. O'Keeffe and presented in the literature (1). An X-band (9 GHz) four-bit, programmable Barker coder and decoder was designed and built and the different theoretical aspects of Barker correlation with a MSW device were then reviewed.

Presented here is a similar device designed to generate, encode, and correlate a thirteen-pulse train, also at 9 GHz. Because of its increased complexity a totally different approach was taken here, both with regard to generating the pulse train as well as the bi-phase encoding. The experimental results presented here, however, pertain to a seven-pulse Barker correlator instead of a thirteen-pulse one, for reasons which will be explained presently. Nevertheless, all considerations concerning the design, building and testing of this device are valid for the thirteen-pulse case. Therefore, in view of our original goal and the results obtained, this work will be presented as a thirteen-bit Barker correlator, which ultimately had to be reduced to seven bits rather than a seven-bit device which can be potentially extended to thirteen bits.

Two identical devices were made, one to serve as the transmitter and the other one as the receiver. When a Barker code is used in the transmitter, the receiver is coded with the time-reversed code, thus becoming a matched filter to the transmitter. The receiver output is then a pulse train where the middle pulse is several times larger than the rest depending on the number of bits used (up to thirteen for Barker coding).

DESCRIPTION OF THE DEVICE

A photograph of the opened box of one of the devices made is shown in Figure 1.

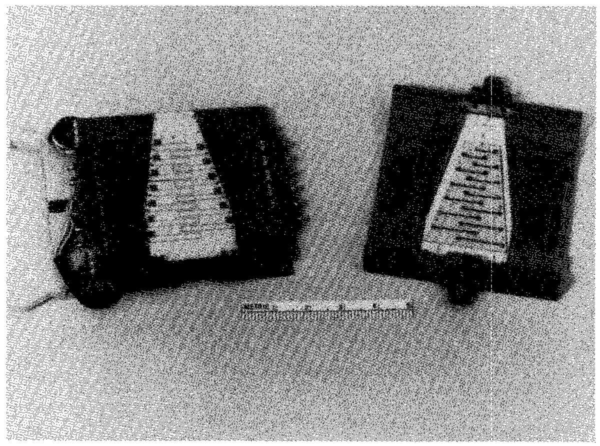


Figure 1. Photograph of the opened box of the device.

This is a magnetostatic forward volume wave device consisting of two parts: The one on the right of the photograph (Figure 1) is the microwave-magnetostatic wave section. The one on the left consists of d.c. loops which provide small magnetic fields for phase encoding.

This device differs from the four-bit one presented in reference (1) in several aspects. In that device the energy was tapped along the delay line and, using PIN-diode switches, the signal from each tap was routed to either one of two paths whose electrical lengths differed by 180°, thus encoding it.

In the Barker coder and correlator presented here, a novel approach to phase encoding the pulse train is introduced. Rather than tapping the magnetostatic wave energy at different points along the delay line (1), the device is composed of narrow YIG delay lines of increasingly long delay. The YIG strips can be seen in Figure 1 through the transparent GGG substrate. As can also be seen, the delay lines feed from a common microstrip input transducer, whereas the output is collected in the two branches of a Wilkinson power combiner.

The phase control mechanism was provided by a conducting loop surrounding each delay line on a plane parallel to them, slightly above the back of the GGG substrate. A direct current circulating through this loop generated a small magnetic field which, by altering the bias to the particular delay line, effected the necessary phase change.

A photograph of the complete device, including the thirteen-channel power supply which provides the necessary currents to all loops, is shown in Figure 2.

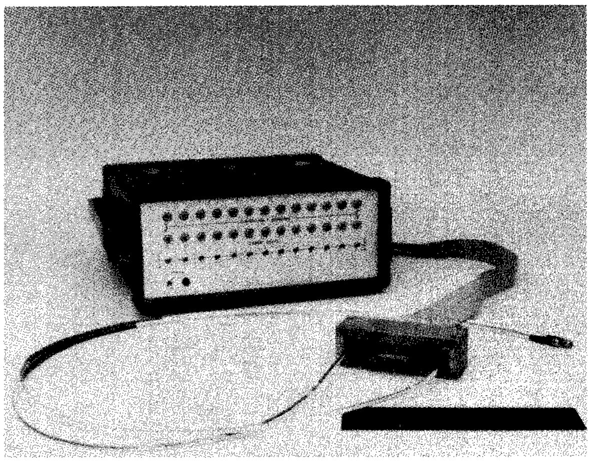


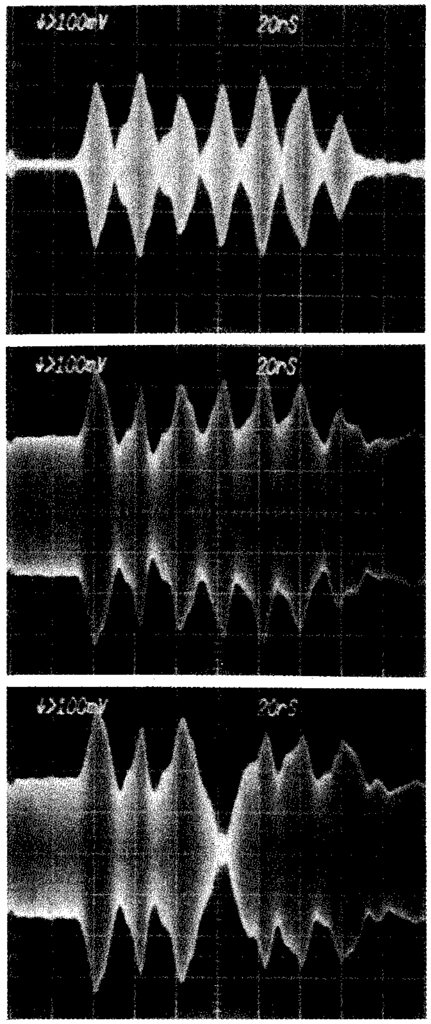
Figure 2. Photograph of the complete device.

EXPERIMENTAL RESULTS

The device was designed for thirteen 3.3 μm thick YIG delay lines with delay increments of 20 nS, so that a 20 nS wide input pulse would generate thirteen 20 nS pulses at the output. Due to a fault in our etching process, however, the 3.3 μm thick YIG strips did not give us satisfactory results. Diamond-saw cut strips 7.5 μm thick were used instead. Because their delay per unit length was lower by half, only seven strips were used. They were placed at every other position occupied by the original thirteen (Figure 1) so as to double the incremental transducer separation between delay lines, thus keeping the incremental delay at 20 nS.

A typical response to a 20 nS pulse is shown on the top photograph in Figure 3. The other two photographs are an example of phase encoding. Figure 3(b) shows the seven-pulse train superimposed on a continuous wave (c.w.) of the same frequency. In Figure 3(c) the phase of the fourth pulse was changed by 180°, thus cancelling the c.w. signal in that time slot.

The two devices were then encoded in this fashion with respect to a c.w. signal. Two codes were used to test the device. First a Barker code, namely +-++--- for the transmitter



a)

b)

c)

Figure 3. Phase encoding example: a) device output; b) device output + c.w.; and c) the fourth pulse is shifted 180° out of phase with respect to the c.w., thus cancelling each other.

(receiver) and ---++-+ for the receiver (transmitter), where a + sign means that the phase of a pulse is the same as the c.w. and - means that it is 180° out of phase with the c.w. Then an all-plus code for both devices was used, that is, all the pulses had the same relative phase. The correlation of the Barker code at the output of the receiver gives a thirteen-pulse train of relative amplitudes 1:0:1:0:1:0:7:0:1:0:1:0:1, whereas the all-in-phase code gives 1:2:3:4:5:6:7:6:5:4:3:2:1. The experimental results are shown in Figure 4(a) and (b). The difference between theoretical and practical results is mainly due to the fact that the pulses were not of the same amplitude. For example, the Barker correlation (Figure 4) shows a ratio between the central peak and the higher side-lobe of about 2.7:1 only, rather than the theoretical 7:1. This is in agreement with a calculation of the result to be obtained taking the amplitudes of the individual responses of each device to a single pulse. The same occurs with the correlation shown in Figure 4(b).

a)

b)

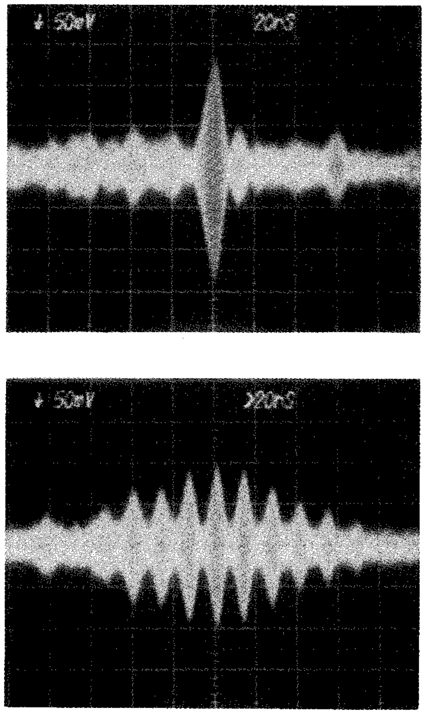


Figure 4. a) Barker and b) all-in-phase correlations.

DISCUSSION AND CONCLUSIONS

The pulse encoder and correlator presented here is a device which differs from most MSW devices hitherto studied in that it is necessary to exercise an accurate control of amplitude and absolute phase (as opposed to its rate of change with frequency) in several delay lines at the same time.

Accurate control (within 1.5 dB) of the relative amplitudes of the seven pulses is both important and difficult to achieve. The power distribution among the seven delay lines is affected by several factors. First, the MSW losses must compensate for the amount of energy available for coupling into each delay line since the delay lines feed from a common transducer. A final adjustment could in principle be made by depositing a thin layer of aluminum (50 to 100Å) on selected YIG strips so as to attenuate those pulses which are highest. This was done in this device for only one delay line.

Second, the standing wave ratio along the input and output (power combiner branches) transducer must be as close to unity as possible since a nonuniform power distribution along these transmission lines would result in some pulses having a higher amplitude than others. In the device presented here, slight modifications in the way the resistor between the two branches of the Wilkinson combiner was originally set in place were made in order to achieve an acceptable result.

The problems of phase control are equally difficult. In the device presented here the main causes for phase drifting were temperature changes. These came from small changes in the laboratory room temperature and from heat dissipated in the d.c. loops. Both were important. Phase in a MSW delay line is affected by temperature changes at an approximate rate of $3\tau°/°C$, where τ is the delay in nS, and by bias field variations at a rate of $\tau°/Oe$.

The room temperature drift effects were practically eliminated by encasing each device in a synthetic-foam insulating material. With respect to the heat generated in the d.c. loops, best results were obtained when a moderate amount of current was allowed to circulate through the loops for some time with the devices in their insulating cases. Once an equilibrium was reached, the changes in current necessary for phase encoding did not alter this equilibrium significantly.

In conclusion, the results obtained (Figure 4) show that reasonably good control of amplitude and phase was obtained. They also show that a thirteen-bit correlator could be built with the same design so long as a good quality 3 μm YIG film is used.

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REFERENCE

1. T. W. O'Keeffe, J. D. Adam, M. R. Daniel, "Magnetostatic Wave Delay Line with Four Biphase Switchable Taps Operating at X-band," 1982 Ultrasonics Symposium Proceedings, p. 522.