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MULTIBEAM TRANSMISSION IN A PARAMETRIC SONAR

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1. INTRODUCTION

In the sector scanning sonar based on transmitter scanning TRANSCAN [1] which has been developed at Loughborough University, a succession of pulses are transmitted each of a different frequency and each with the beam pointing in a different direction. This enables the signals arriving from the different directions to be separated on reception on the basis of their frequency.

This method of operation is applicable both at the primary frequency of transmission and, more importantly, at the low secondary frequencies which can be generated by the non-linear interaction in the water (parametric operation). Experimental results using these methods have been reported earlier [2].

However the bandwidth available within the system limits the length of the pulse that can be used in each channel, and hence for a 16 channel system the total duration of the transmission can be very significant, limiting the minimum range that can be observed. Hence there is a desire to transmit the beams concurrently rather than in succession. There is of course a concomitant loss in total energy transmitted, but in certain circumstances this can be accepted. Since, at the primary frequency, the system is essentially linear theory suggests that it should be possible to superimpose several beams and then separate them without mutual interference. Earlier papers have shown both by computer simulation and practical measurement that this can be achieved [3][4].

However when transmitting several beams each of which comprises two frequencies (or is suitably modulated with the intention of producing a secondary beam at a low frequency) the possibilities of unwanted interaction in the non-linear domain suggests that difficulties might arise. A theoretical treatment of this problem is rather intractable and the simplest method seemed to be to carry out some experimental work to investigate the possibilities.

This paper describes some experiments which were aimed at establishing whether or not it would be possible to use concurrent transmission when operating in the parametric mode.

2. MEASURING EQUIPMENT

The Sonar Transmitter used was the high power version of the two equipments which have been developed at LUT [5]. It also used a new signal generator source based on the transputer [6]. This is a very flexible system and allows a large number of different beams to be generated. The individual waveforms required for each stave of the transducer are generated digitally and stored in 16 channels of 64K 16 bit memory. This data can be read out at any desired repetition rate under control of the host computer. The outputs from these memories, after D/A conversion, are fed to the individual power amplifiers and so to the array.

The ARRAY used for these tests comprised 256 elements arranged as 16 staves of 16 elements, the spacing of the elements being equal to 1 λ at the centre frequency of operation (40 kHz). A full description of the array is given in ref [7]. To run the array at full power without causing cavitation it is necessary to operate at about 30 metres.

Although for beam-pattern measurements we normally use an automatic beam-pattern measurement system which has been developed at LUT, it was unfortunate that for these trials the unit was not available due to the failure of an O-ring in the pan-and-tilt unit. The array had to be rotated by hand which resulted in rather less smooth beamplots.

A hydrophone was suspended about 70 metres from the array at a depth of about 30 metres. A spectrum analyser was used to measure the levels of all the various frequency components.

3. EXPERIMENTS

There are two basic methods of generating the low frequency in the water:-

1, Square wave modulation of the primary carrier at the desired NLA frequency. Details of this method can be found in reference [8].

2, Generating two closely spaced frequencies which interact in the water to produce the difference frequency.

In these experiments the second method was used since, although this is slightly less efficient [8], the resulting spectrum is very much cleaner. In figure 1 we see an example of the spectrum produced by the modulation method and in figure 2 that produced by the two frequency method.

The new generating system allows a large number of independent beams to be generated each beam having a defined direction and frequency. To operate in the parametric mode using the two frequency method it is simply necessary to define two beams pointing in the same direction and the frequencies of the individual beams be such as to produce the desired parametric frequency in the water.

In fact more than one parametric frequency can be generated within one direction simply by increasing the number of beams. In figure 3 four primary beams are produced pointing in the same direction resulting in six secondary frequencies. The frequencies of the beams are 38, 39, 41 and 45 kHz producing NLA products at 1, 2, 3, 4, 6 and 7 kHz. The improvement of conversion efficiency with the increase in the secondary frequency can be seen.

Similarly in figure 4 the spectrum for ten primary frequencies is shown. The shape of the low frequency components is rather interesting. Since the ten primary frequencies are equally spaced at 1 kHz there are 9 combinations which will produce the 1 kHz secondary component. For 2 kHz there are 8 combinations and so on until the maximum of 9 kHz is reached which has only one combination to contribute to its magnitude. On the other hand the efficiency increases with the secondary frequency in a square law fashion and hence we see the particular shape of the secondary spectrum in figure 4.

To produce a number of NLA beams pointing in different directions we simply replicate the method used for one NLA beam i.e. a pair of beams separated in frequency by the required difference frequency is used for each direction. In figures 5 to 7 we see the measured results for 2, 4, and 8 NLA beams respectively. The results were obtained by rotating the transmitting array and taking a spectrum of the hydrophone signal for each direction. The individual frequency components can then be plotted as shown in the figures. The individual beams are plotted on separate diagrams in figure 7 since otherwise the figure becomes too confused.

4. CONCLUSIONS

The results obtained show that it is possible to generate concurrent NLA beams of different frequencies pointing in different directions in spite of the interaction that takes place in the vicinity of the transmitting array. There is evidence of leakage of frequencies into the wrong beam but these components are considerably down on the peak response and are lower than the nominal sidelobes of a linear array.

It should be noticed that as the number of beams is increased the power in each beam is reduced. In fact because the present system is peak power limited the reduction is quite large, each beam being below the peak power by 20 times the logarithm of the number of beams. The non-linear effect below saturation is proportional to the square of the power so that this loss is very significant.

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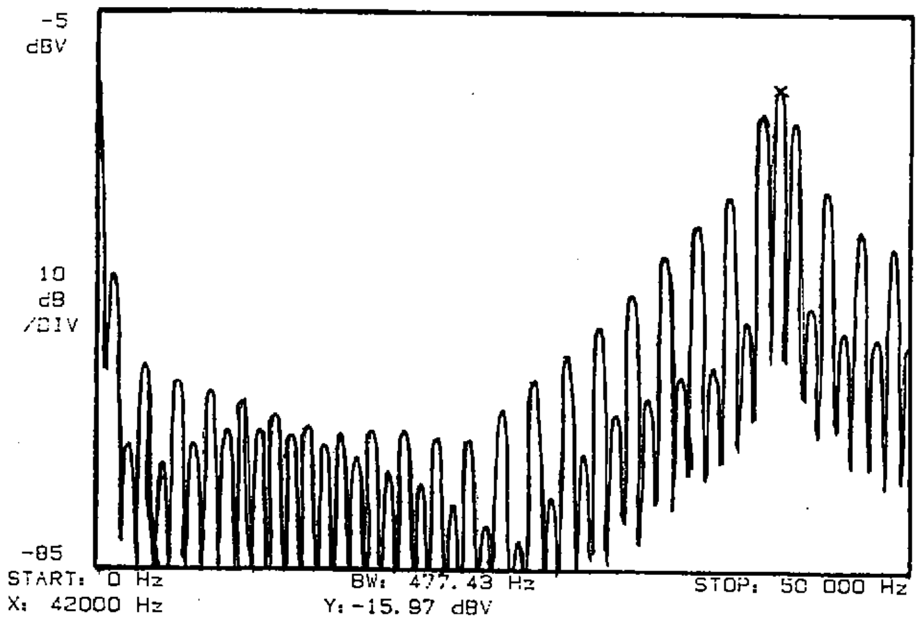


FIG. 1. SPECTRUM OF SQUARE WAVE MODULATED SIGNAL

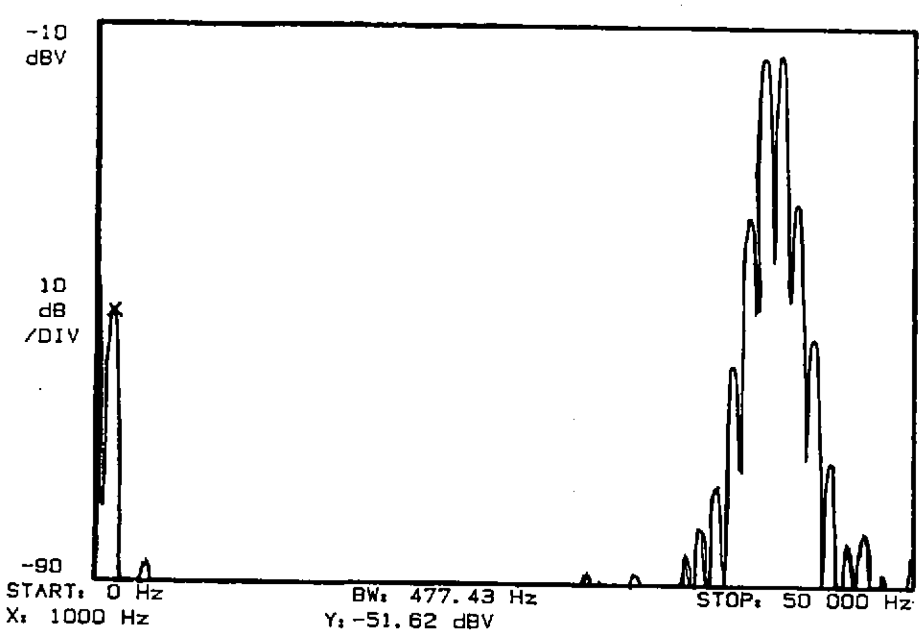


FIG. 2. SPECTRUM USING TWO FREQUENCY METHOD

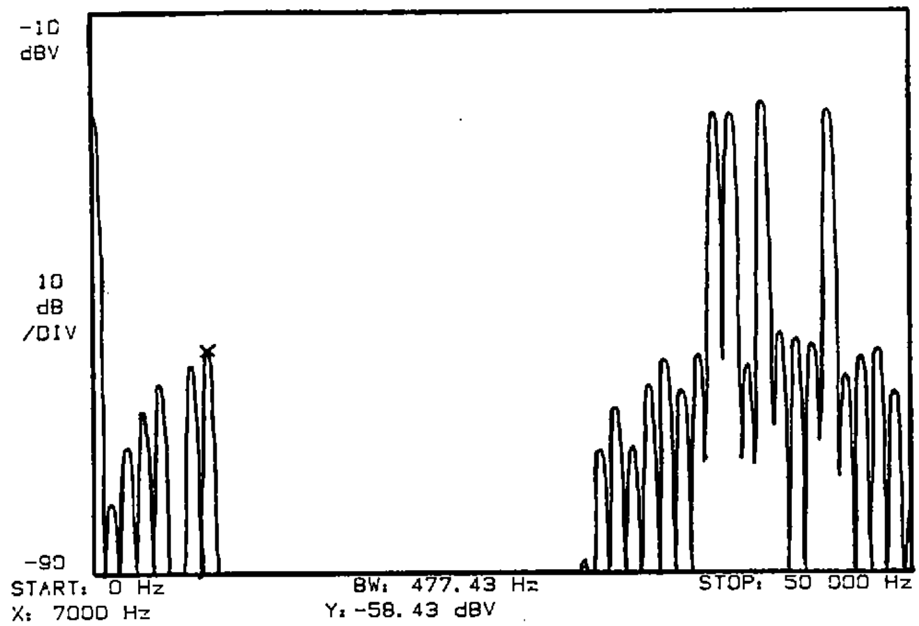


FIG. 3. SPECTRUM OF FOUR PRIMARY FREQUENCIES IN ONE DIRECTION

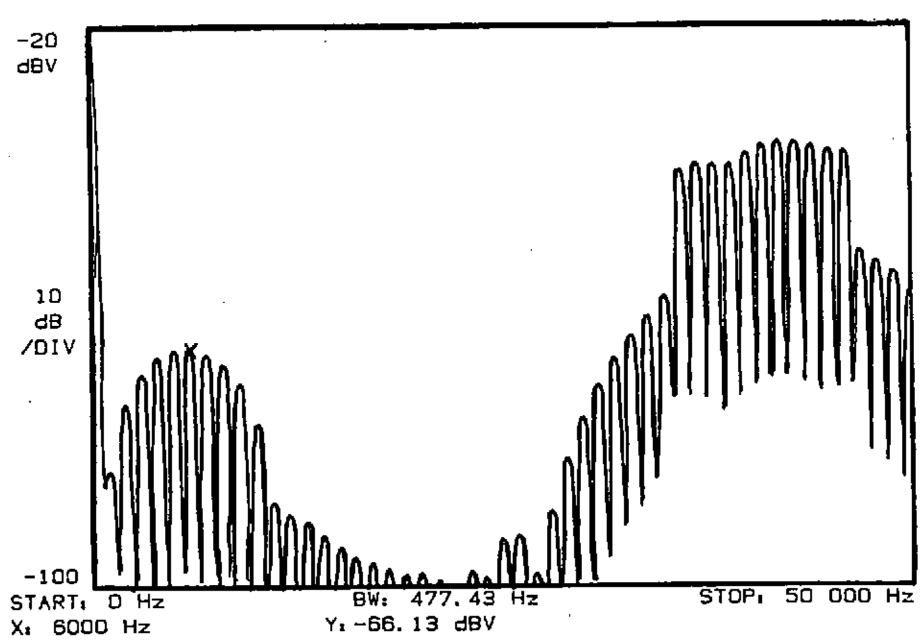


FIG. 4. SPECTRUM OF TEN PRIMARY FREQUENCIES IN ONE DIRECTION

FIG. 5. 2 NLA BEAMS WITH DIFFERENT FREQUENCIES AND DIRECTIONS

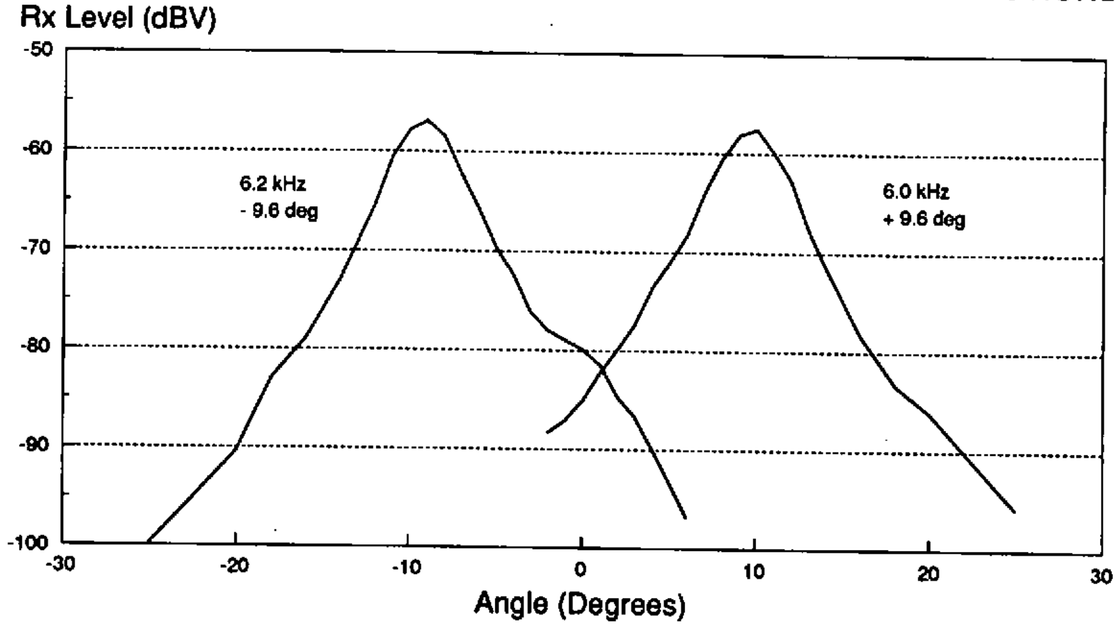
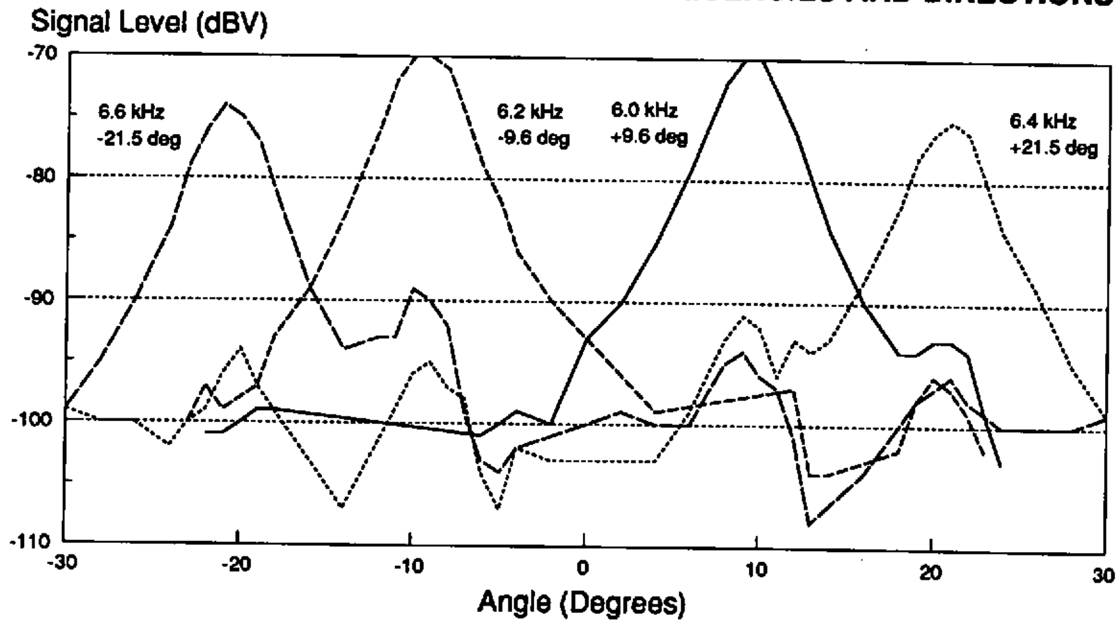


FIG. 6. 4 NLA BEAMS WITH DIFFERENT FREQUENCIES AND DIRECTIONS



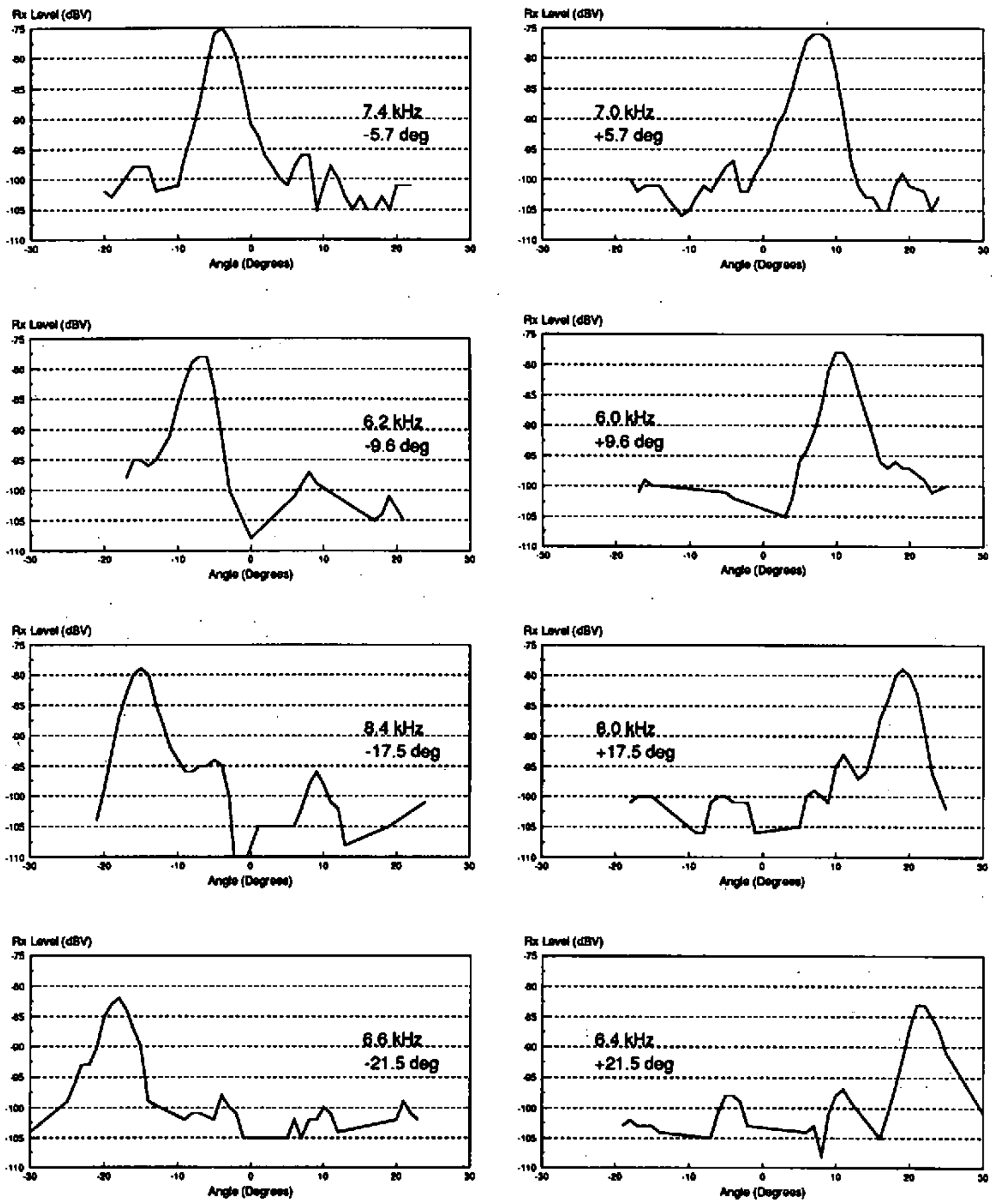


FIG. 7. 8 NLA BEAMS WITH DIFFERENT FREQUENCIES AND DIRECTIONS