

PROBLEMS IN THE DESIGN OF STRING SECTION CONTROLLERS.

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ABSTRACT

Possible choices for string section controllers are discussed from the standpoint of maximum system reliability and replacement cost. Choices include controllers for complete strings (24 modules), half-strings and quarter-strings. The corresponding number of data channels to shore are 9, 18 and 36. Up to 18 optical fibers are now feasible, and wavelength duplexing allows 36 channels with 18 fibers. The grounds for choice among these possibilities are discussed, and the need for Monte Carlo calculations to make a final determination is stressed.

RELIABILITY CONSIDERATIONS

The delay in the publication of the Proceedings of the 1988 DUMAND Workshop on Signal Processing resulted in the DUMAND renewal proposal being written without taking into account the highly significant results of that workshop. This was fortunately not the case for deployment, for which the present highly satisfactory solution became available only after the workshop.

In consequence of the results of the signal processing workshop, a fundamental reorientation of our attitude toward the design of the components of DUMAND II is now required. The overriding consideration in design must now be reliability. This is not a new idea, but it cannot be overstressed.

The quest for high reliability, and therefore infrequent interruptions for string replacement, inevitably centers on the string bottom controller, which is the only active node between the individual module and the shore station. The other nodes are all passive, and their reliability is built into them. In addition, the individual module reliability must be as high as possible.

In order to consider the various alternatives available, let us start by renaming the string bottom controller the string section controller (SSC). This makes explicit the option of moving up the SSC node from the whole string to only a portion of it. In practice the most important divisions will be into half- and quarter-strings. The original SBC would have to control 24 modules; the half-string SSC controls 12, the quarter-string only 6. Correspondingly, the full SBC requires only one shore communication channel per string, the half-string SSC requires two, and the quarter-string 4.

Let us now consider the implications in terms of system reliability. It has already been (wisely) decided that the data transmission in all these alternatives

will be time-ordered, thus greatly simplifying the data-handling problem at the shore end of the system. In order to compare the several alternatives we must examine how the communication channels are to be provided.

The most straightforward way would be to add optical fibers for each new channel. The full SBC alternative then requires nine channels, the half-string SSC 18 and the quarter-string 36. The latest word from Wilkins on multi-fiber undersea cables gives 20 as the maximum number already achieved, with a good possibility of going higher. Thus the half-string alternative is currently feasible; the quarter-string requires one more stage of data multiplexing to put two channels on a single fiber, to keep the total down to 18.

At the present cost of 50 cents/meter, each additional 40-km fiber will cost \$20K. Going from 9 to 18 fibers then costs \$200K, putting in a safety margin for other cable costs required in raising the number. In addition there are more connectors on the junction box and the string anchors, unless the possibility mentioned by Wilkins of multi-fiber single-mode underwater connectors materializes. This additional cost cannot be considered excessive if the reliability gain is sufficient. It may perhaps be partially compensated by savings in SSC costs.

For quarter-string SSC's we require wavelength duplexing: i.e. using two separate independent laser transmitters on each fiber at different wavelengths (1.3 and 1.5 microns), with independent non-interfering receivers at the other end. All of this technology is now commercially available and in current use. The Navy has presently in operation an undersea link fully implemented at these two wavelengths.

We now ask what are the implications of each possibility in terms of reliability of the system as a whole. In the event of SSC failure the consequences of a single failure are progressively less severe, resulting in the loss of 24, 12, and 6 modules respectively. In addition, for half- and quarter-strings it can be so arranged that the dead modules are not contiguous, but in distributed locations along the string; this mitigates the effect of a single failure. We need to investigate, via Monte Carlo simulations, how many failures of each type can be tolerated before the array performance falls below a designated floor; and we need to estimate the relative MTBF's of the various SSC's.

The relative reliabilities of the several SSC's are clearly in inverse order of the number of modules controlled. The quarter-string controller needs to be four times as reliable as the full-string one in order to match the number of modules lost per unit time. However, there is a significant difference, in that the four quarter strings put out of commission will in general be on different strings.

STRING REPLACEMENT.

It is not entirely obvious that this is an unalloyed advantage. For example, it may turn out that where the loss of, say, two strings with a full-string controller

requires immediate replacement, the loss of eight quarter-strings would not. (This is a question that can only be decided by Monte Carlo simulations.) If it turns out that replacement is needed after, say, eight quarter-string failures, we are then faced with the problem of replacing up to eight strings rather than one. This implies the availability of a rather large number of spare modules and strings; or alternatively, of repairing the removed strings and then redeploying them, which might be a lengthy process. In any case, it is clear that while subdividing strings delays the need for replacement, it makes replacement far more complex and expensive.

In addition to SSC failures, there are individual module failures. If the individual module failure rate is high, it may be that the replacement rate will be governed by the individual module failure rate rather than the SSC failure rate. If that is the case, and we find, for example, that replacement is required after fifteen percent of the modules fail, then 36 modules scattered over the entire array will need replacement. This could well be equivalent to removing and redeploying the entire array.

It appears from these considerations that the replaceability of complete strings, valuable though it is, may not be all we need. If we cannot find a method for replacing individual modules under water – and that seems most unlikely – we will have to try to assure that the type and rate of failure is such that replacement of only a few strings at a time is required. Alternatively, it would be highly desirable to perfect a technique for retrieving a string, quickly replacing the defective modules at sea, and redeploying the same string.

The operation of string replacement requires, first, the availability of a replacement string and the vessel (probably the Kaimalino) to deploy it. Second, an ROV and its attendant control vessel is required twice; once to disconnect the faulty string, and once to connect the replacement. This could be reduced to once if either a) the replacement string is deployed in a different location from the one it replaces, or b) the faulty string can be retrieved without disconnecting its cable. The latter would be possible if the anchor is in two parts, which can be separated by a signal from shore or from the attendant ship. The Kaimalino or its equivalent is required to deploy the new string and to collect the discarded one. Furthermore, since the Kaimalino can carry only one string at a time, the replacement of each string requires a trip back to port to reload – unless, as mentioned above, module replacement is feasible at sea.

This operation, requiring the coordinated scheduling of two ships, is thus a major one, and scheduling it may well involve delays of many months. Consequently it will be worth considering the possibility of scheduling string replacements as preventive maintenance at predetermined intervals. It is also clear that decisions concerning the number of channels and the mode of division of strings will strongly affect the maintenance procedure.

SSC Failures.

From the electronic standpoint, it seems likely that SSC's for six modules can be made considerably better than four times as reliable as SSC's for 24 modules. They are not only simpler, but they handle far less data. Increasing the number of data channels always involves simplifying the data-handling process.

Other duplexing alternatives need consideration. With half-string controllers, wavelength duplexing would allow us to stay with 9 fibers. The relative cost and reliability of these alternatives requires detailed examination.

We have not considered further increase in the number of data channels by means of other duplexing techniques. If four independent wavelengths were available, nine fibers would be adequate for quarter-string controllers. Some distant future day, 24 independent channels may be available (without time-sharing) on the same fiber, in which case the string-section controller no longer controls data.

In conclusion, it is clear that extensive Monte Carlo calculations are required to assess the effects of module failures and partial string failures on the operation of the array, and to give us a basis for deciding when replacements need to be made. It is also clear that replacement considerations must seriously affect SSC choice, and that it will be highly desirable to be able to replace defective modules at sea.